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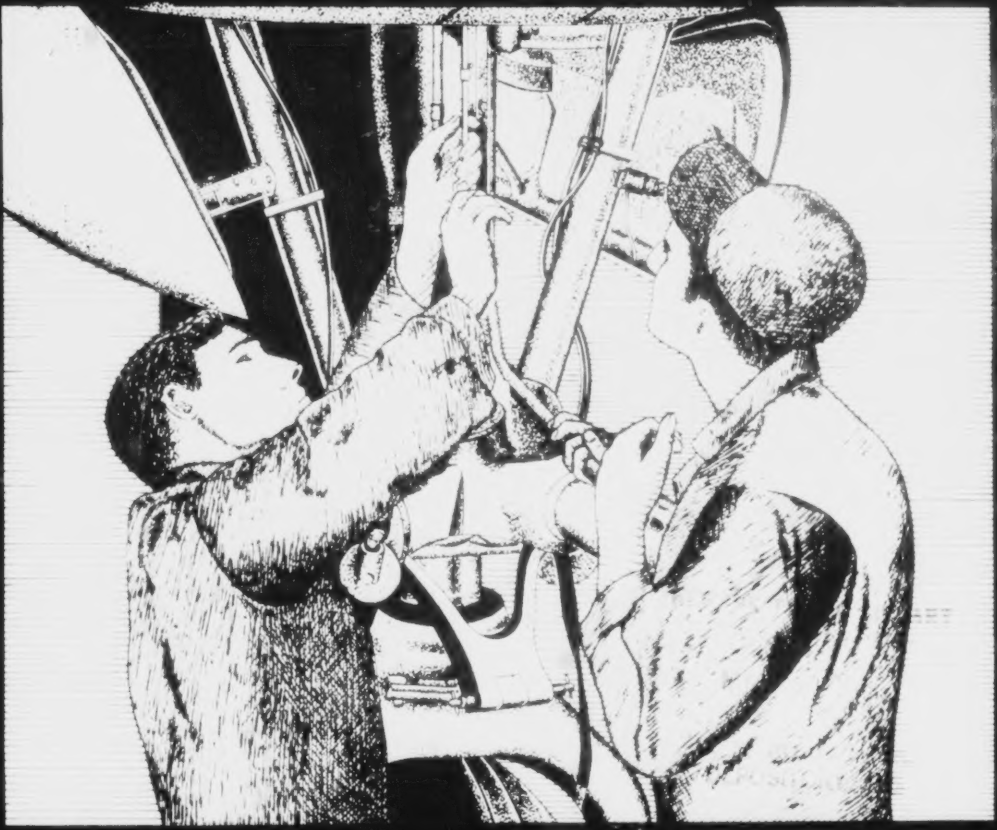

AVIATION

STRUCTURAL MECHANIC S 1 & C

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL
AND NONRESIDENT CAREER COURSE

NAVEDTRA 10311-C2

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PREFACE

The ultimate purpose of training Naval personnel is to produce a combatant Navy which can ensure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable ambitious Aviation Structural Mechanics (S) to help themselves fulfill the requirements of their rating.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational qualifications of the Aviation Structural Mechanic S (AMS) rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM. The NRCC is designated a major revision, and retirement point credit will be granted to Naval Reservists who complete (or retake) it successfully.

This training manual and nonresident career course was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical review of the manuscript was provided by personnel of the AMS (B) School, NAS, Memphis, Millington, Tennessee, and the Naval Aviation Integrated Support Center, Patuxent River, Maryland. Technical assistance was also provided by the Naval Air System Command.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 4

AIRFRAME REPAIR, ALIGNMENT, AND MAINTENANCE

CAUSES OF DAMAGE

Damages to the airframe are many, and may vary from those which are classified as negligible to those which are so extensive that an entire member or portion of it must be replaced. The slightest damage could eventually affect the flight characteristics and the mission of the aircraft. The most common cause of damage to the airframe are collision, stress, heat, corrosion, foreign objects, fatigue, and combat damage.

COLLISION

This type of damage is often the result of carelessness of maintenance personnel, and varies from minor damage, such as dented or broken areas of skin, to extensive damage, such as torn or crushed structural members and misalignment of the aircraft. Extreme care should be exercised in all ground-handling operations. Runways, taxiways, and parking areas should be kept clean at all times, to eliminate damage to the aircraft.

CORROSION

Damage to airframe components and the structure caused by corrosion will develop into permanent damage or failure if not properly treated. The corrosion control section of the Maintenance Instructions Manual describes the maximum damage limits. These limits should be checked carefully; and if they are exceeded, the component or structure must be repaired or replaced.

FATIGUE

This type of damage is more noticeable as the operating time of the aircraft accumulates. The damage will begin as small cracks caused by vibration, oil cans, and various other loads imposed on skin fittings and load-bearing members where the fittings are attached.

FOREIGN OBJECT

This damage is caused by handtools, bolts, rivets, nuts, etc., left adrift during ground operations of the aircraft. Because of jet aircraft design, large volumes of air are required for its efficient operation. During ground operations this air is pulled through the inlet ducts, and the airflow induces a strong suction which picks up these objects that are left adrift; therefore, it is of utmost importance that the area around the aircraft be policed and cleaned up before ground operations begin.

COMBAT DAMAGE

Damage from enemy gunfire is usually quite extensive and often not repairable. When a projectile strikes sheet metal, it heats the metal in the vicinity of the damage. If the projectile passes through the component or structure, it will leave a larger hole on the opposite side from where it entered, the metal becomes brittle around the damaged area as a result of the heat, and minute cracks are created by the impact of the projectile. As these cracks open up under vibration, the repair procedure should be followed with extreme care and only after a rigid inspection.

HEAT

Certain areas of high performance aircraft are exposed to the dangers of high temperatures. These areas usually include the engine bleed lines, fuselage sections around the engine, the aft fuselage and horizontal stabilizer, and the wing sections around the boundary layer control system. Damage could be caused by fire resulting from failure of the blast panels or insulation. Some aircraft Structural Repair Manuals include diagrams that illustrate the danger areas.

STRESS

This type of damage is usually identified by loosened, sheared, or popped rivets; wrinkled skin or webs; and cracked or deformed structural members. This damage is usually caused by violent maneuvers or hard landings. When the pilot reports these discrepancies on the yellow sheet, a thorough inspection of the entire aircraft must be performed.

INVESTIGATION OF DAMAGE

When any part of the airframe has been damaged, the area around the damage should be cleaned of grease, dirt, and paint before an investigation can be made, and the extent of damage determined. There are three methods of inspection that can be used to insure that a thorough investigation has been made. The three methods are visual inspection, hardness testing, and nondestructive inspection for cracks.

VISUAL INSPECTION

A thorough inspection of the structure should be made for dents, scratches, abrasions, punctures, cracks, distortion, loose joints, breaks, and buckled and wrinkled skin. All riveted and bolted joints in the vicinity of the damaged area should be checked for elongated holes, and loose, sheared, or damaged rivets or bolts. If any doubt should exist about the failure of a rivet or bolt, the fastener should be removed for a more thorough inspection. All access panels, hatches, and doors should be opened for the inspection of the internal structure.

A Borescope (precision optical instrument) can be used to great advantage for the inspection of the internal structure. Areas may be examined with this instrument without being disassembled by removing fasteners, inserting the Borescope, and viewing the area through the eye piece. The fasteners should be removed in a regular pattern to be sure that a complete inspection has been made.

The adjacent structure should be inspected to determine if secondary damage has resulted from the transmission of shock or the load that caused the primary damage. A shock at one end of a structural member may be transmitted to the opposite end of the member, causing sheared rivets or other damage at a considerable distance from the primary damage. In estimating the extent of damage, be sure that no secondary damage remains unnoticed.

Every precaution must be taken during the inspection to insure that all corrosion is detected, especially in places where it will not be visible after repair. Past experience has proven that corrosion occurs more often in parts of the structure that are poorly ventilated and inaccessible corners of internal joints that prevent proper water drainage.

HARDNESS TESTING

When fire has damaged the airframe, the paint will be blistered or scorched and the metal will be discolored. When these conditions exist the affected area should first be cleaned and the paint removed. Following this, a hardness test should be made to determine if the metal has lost any of its strength characteristics. This test can be performed with the Barcol or Riehle portable hardness tester, described in detail in chapter 5. If the material to be tested is to be removed from the airframe, then a more reliable test can be made by the use of a standard bench type tester (also described in chapter 5). If the alloy to be tested is either clad or anodized, the surface coating must be removed to the bare metal at the point of penetrator contact. This is necessary because clad surfaces are softer, and anodized surfaces are harder, than the base alloy.

INSPECTION FOR CRACKS

The existence of suspected cracks or the full extent of apparent cracks in structural members cannot be accurately determined by visual inspection. In cases where it is necessary for cracks to be accurately defined, a penetrant inspection is usually performed.

Fittings should receive a special investigation if they are cracked, since this could cause an entire component to fail. Fittings are used to attach sections of wings together and wings to fuselage, as well as attachment of stabilizers, control surfaces, landing gear, engine mounts, etc. The penetrant method of inspection can be used to detect surface cracks in fittings, and the magnetic particle method used to detect subsurface cracks in ferrous fittings. Inspection of metals is described in detail in chapter 7.

CLEANUP OF DAMAGE

Simultaneously with the investigation of damage, clean out all jagged holes, tears, or damaged material. The cleaned out sections must include all the area in which minute cracks are present. The affected area must be cut out and rounded to form a smooth regular outline. If a rectangular- or square-shaped cutout is made, the radii for the corners should be a minimum of one-fourth inch, unless otherwise specified. All burrs should be removed from the edges of the cutout.

All dented plates should be restored to their original shape if possible. Shallow abrasions or scratches should be burnished with a burnishing tool which will compress the projecting metal along the edges down into the scratch. Burnishing has no cutting action and removes no metal. When surface irregularities are smoothed out by burnishing, the stress concentration will be lessened by uniform distribution of the stresses.

CAUTION: Deep scratches and abrasions must be treated as complete breaks.

CLASSIFICATION OF DAMAGE

After the extent of damage has been determined, it should be classified in one of the following categories: Negligible damage, damage repairable by patching, damage repairable by insertion, or damage necessitating replacement of parts. Before proceeding with the repair of the airframe, it is necessary that the applicable Structural Repair Manual be consulted for the procedure and materials to be used. If the applicable manual is not available, The General Manual for Structural Repair, NA 01-1A-1, may be used. If any conflict should exist between the two manuals, the specific manual takes precedence.

NEGLIGIBLE DAMAGE

Negligible damage is that damage or distortion which may be allowed to exist as is, or corrected by some simple procedure such as removing dents, stop-drilling cracks, burnishing scratches or abrasions, without placing a restriction on the flight status of the aircraft. Before classifying a damage as negligible, make sure the damage complies fully with the manufacturer's specified limits of negligible damage.

DAMAGE REPAIRABLE BY PATCHING

Damage which can be repaired by installing a reinforcement or patch to bridge the damaged portion of a part may be classified as a damage repairable by patching. Reinforcement members are attached to the undamaged portions of the part to restore full load-carrying characteristics and airworthiness of the aircraft. Damage repairable by patching is specified for each member of the airframe.

DAMAGE REPAIRABLE BY INSERTION

Damage which is extensive enough to involve a major portion of a member, but which is not so extensive as to require replacement, is classified as damage repairable by insertion. The repair is made by inserting a new section and splicing it to the affected member.

DAMAGE NECESSITATING REPLACEMENT

Damage which cannot be repaired by any practical means is classified as damage necessitating replacement. Short structural members ussually must be replaced because repair of such members is generally impractical. Figure 4-1 shows typical examples of damage classification and a typical repair for each.

TYPES OF REPAIR

The type of repair to be made will depend on the materials, tools, amount of time available, accessibility to the damaged area, and the maintenance level. The types of repair are permanent, temporary, and one-time flight (ferry). Repairs are also classified as either internal or external.

A permanent repair is one which restores the strength of the repaired structure equal to or greater than its original strength; and at the same time satisfies aerodynamic, thermal, and interchangeability requirements. This is necessary to insure the designed capabilities of the aircraft.

The temporary repair restores the load carrying ability of the structure but is not aerodynamically smooth or able to satisfy interchangeability requirements. This repair should be replaced by a permanent type as soon as possible, in order for the aircraft to be restored to its normal condition.

The one-time flight repair restores a limited load-carrying ability to the damaged structure in order to fly the aircraft to a Depot maintenance activity for a permanent repair. When this type of repair is made, the aircraft cockpit should be placarded to limit the performance of the aircraft.

INTERNAL STRUCTURAL REPAIR

The repair of internal structures concerns the repair or replacement of extruded parts used as stringers, webs used as bulkheads, and formed parts such as ribs and formers.

After the damage has been inspected and classified, the next consideration is to plan the repair so that it may be assembled in the proper sequence. Before the removal, repair, or replacement of a structural member is undertaken, the adjacent structural members of the aircraft must be supported so that proper alignment is maintained throughout the operation.

Fabrication of parts

Information needed to fabricate replacement parts is usually found on blueprints, while information concerning repairs may be found in the aircraft Structural Repair Manual. The Structural Repair Manual contains information on extrusions and the necessary data for the fabrication of various sheet metal equivalents.

The aircraft Structural Repair Manual will indicate the type of material to be used in each repair. If the correct material is not available, the General Manual for Structural Repair (NA 01-1A-1) should be checked for an acceptable substitute.

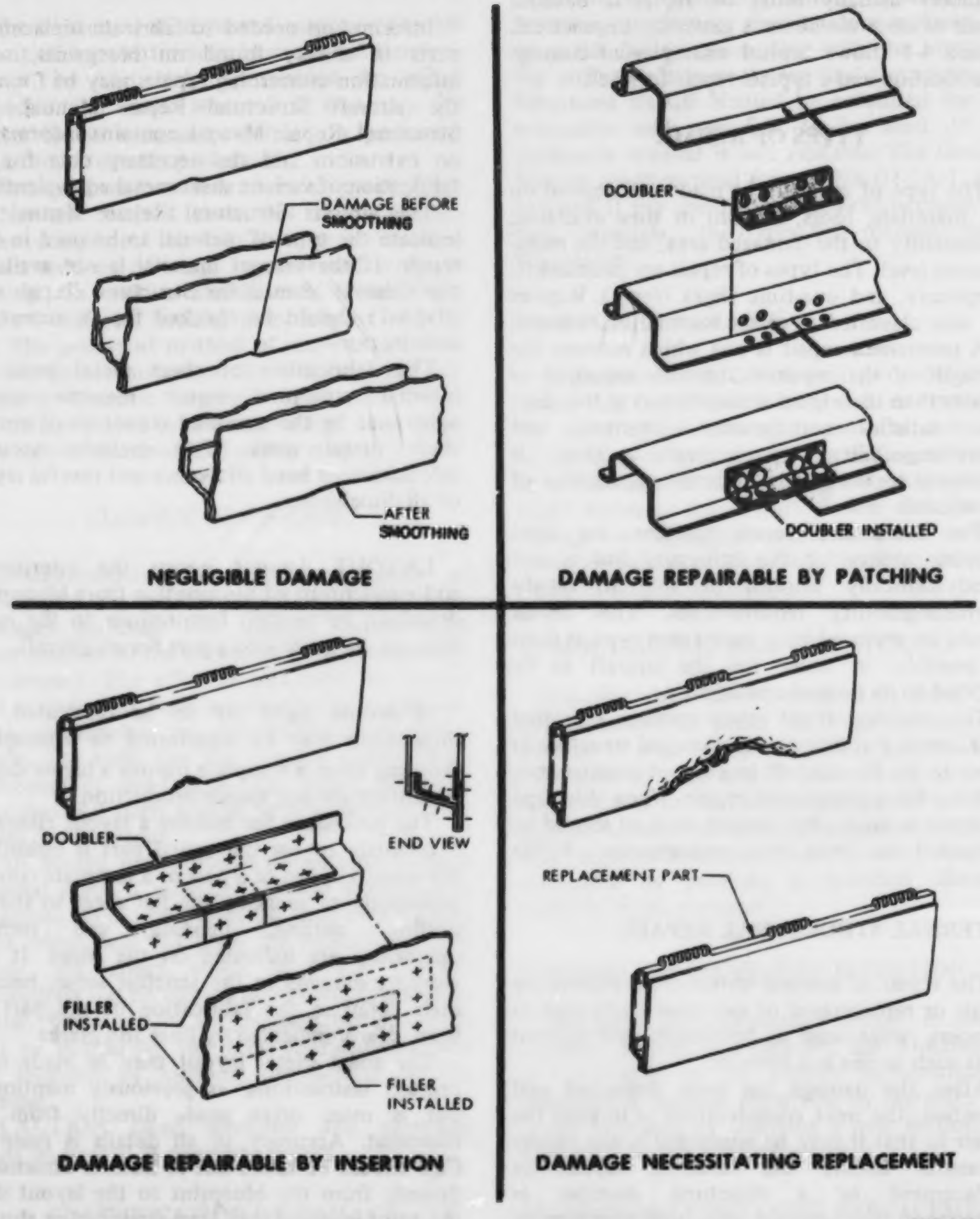
The fabrication of sheet metal parts for internal structural repair requires careful adherence to the accepted standards of aircraft sheet metal work. This includes accurate calculation of bend allowance and careful layout of all dimensions.

LAYOUT.–Layout means the interpreting and transcribing of information from blueprints, drawings, or written instructions to the metal that will be made into a part for an aircraft.

If several parts are to be fabricated, the dimensions may be transferred to a template. Working from a template insures a higher degree of uniformity and speeds production.

The procedure for making a layout either for a template or for the actual part is essentially the same. Layout of a part or a template consists principally of marking the flat sheet so that all drilling, cutting, bending, and forming operations are indicated on the sheet. It is a working drawing in the strictest sense, because each detail in the fabrication of the part has been clearly indicated by lines and marks.

The sheet metal layout may be made from printed instructions, as previously mentioned, but is more often made directly from the blueprint. Accuracy in all details is essential. Care should be taken not to transfer dimensions directly from the blueprint to the layout since the print material may have stretched or shrunk, causing minor distortion of the dimensions. Measurements indicated on the blueprint are made on the layout.


DAMAGE BEFORE SMOOTHING
AFTER SMOOTHING
NEGLIGIBLE DAMAGE
DOUBLER
DOUBLER INSTALLED
DAMAGE REPAIRABLE BY PATCHING
END VIEW
DOUBLER
FILLER INSTALLED
FILLER INSTALLED
DAMAGE REPAIRABLE BY INSERTION
REPLACEMENT PART
DAMAGE NECESSITATING REPLACEMENT

AM.441

Figure 4-1.—Classification of damage.

Details are often left out and must be developed in the shop. The AMS may, for example, find that he must add several dimensions, then figure the bend allowance for the material consumed in each bend before he is able to lay out the overall length or width of a part.

On very accurate layouts, a magnifying glass is frequently used as an aid to permit precision work. A magnifying glass enlarges the graduations on a scale, rendering them easier to read. It helps locate center punchmarks, and it facilitates a close inspection of the accuracy of the completed layout.

To begin the layout, one edge of the metal should be straight. All measurements can then be based on this edge of the sheet. Lines at a known angle or parallel to the straight edge can be made by marking off points from a combination square held firmly against this edge of the sheet.

If it is impossible to obtain a straight edge on a sheet to start a layout, or if the distance from the edge is too great, a reference line may be used. The reference line may be made by connecting any two points with a straight line. Perpendiculars to the reference line may be geometrically erected by using compasses or dividers to form a cross. This cross, accurately constructed, may be used as the basis for almost any type layout.

A scriber must never be used for drawing lines on aluminum or magnesium except to indicate where the metal is to be cut or drilled. All other lines must be drawn with a pencil. The pencil mark should be removed from aluminum and magnesium to prevent an electrolytic action that will eventually cause corrosion. It can be removed with isopropyl alcohol or MEK. Even a shallow line that is cut in the surface of the metal may cause cracking and eventual failure.

In the layout of a part, plan the bending and forming operations so that each step is made in the proper sequence. If the steps are not made in the proper sequence, the part may become so bulky that it will be impossible to insert it in the brake to make the final bend.

Since layout of replacement parts involves the interpretation of blueprints, Blueprint Reading and Sketching, Navpers 10077-C, should be reviewed.

BEND ALLOWANCE.–Since bend allowance is discussed in detail in Aviation Structural Mechanic S 3 & 2, NavTra 10308-C, the information in this chapter is limited to illustrating the minimum bend radii table and the bend allowance table for some of the commonly used metal thicknesses and bend radii, and showing the use of the empirical bend allowance formula.

Table 4-1 shows the minimum bend radii generally accepted by the aircraft industry.

Table 4-2 shows the bend allowance per degree of bend for some of the commonly used thicknesses and bend radii. This table is based on the empirical formula for bend allowance illustrated in figure 4-2.

Stringers and Their Repair

A stringer is a spanwise structural member designed to stiffen the skin and aid in maintaining the contour of the structure. Stringers also transfer stresses from the skin to the bulkheads and ribs to which they are attached. Stringers are not continuous throughout the structure as are longerons, and are not subject to as much stress. Stringers are made from both extruded and rolled sections and are usually in the form of C channels, angles, or hat sections.

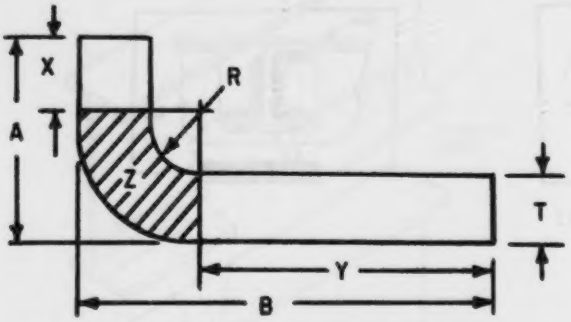
Figure 4-3 illustrates one method used in repairing a damaged stringer by patching. The repair consists of a reinforcement splice and a filler splice. The reinforcement splice should be long enough to extend a minimum of four times the width of the leg of the stringer on each side of the damaged area. The cross-sectional area of the reinforcement splice must be equal to or greater than the stringer itself. The damage is cleaned out to a smooth contour with corner radii, and a filler of the proper thickness is prepared to fit in the cleaned out area. If possible, always make both ends of the cutout midway between two rivets, so that the existing rivet pattern can be maintained in the repair. Cut the filler splice 1/32 inch shorter in length than the cutout section. This will allow a 1/64-inch clearance between each end of the filler splice and the stub ends of the stringer, thus eliminating any possibility of stress developing from contact between the two parts.

Table 4-1.—Minimum bend radii for aluminum alloys

Designation	Gage							
	0.020	0.025	0.032	0.040	0.050	0.063	0.071	0.080
2024-O	1/32	1/16	1/16	1/16	1/16	3/32	1/8	1/8
2024-T4	1/16	1/16	3/32	3/32	1/8	5/32	7/32	1/4
5052-O	1/32	1/32	1/16	1/16	1/16	1/16	1/8	1/8
5052-H34	1/32	1/16	1/16	1/16	3/32	3/32	1/8	1/8
6061-O	1/32	1/32	1/32	1/16	1/16	1/16	3/32	3/32
6061-T4	1/32	1/32	1/32	1/16	1/16	3/32	5/32	5/32
6061-T6	1/16	1/16	1/16	3/32	3/32	1/8	3/16	3/16
7075-O	1/16	1/16	1/16	1/16	3/32	3/32	5/32	3/16
7075-W	3/32	1/32	1/8	5/32	3/16	1/4	9/32	5/16
7075-T6	1/8	1/8	1/8	3/16	1/4	5/16	3/8	7/16

Table 4-2.—Allowance per degree of bend for aluminum alloy

T R	0.020	0.025	0.032	0.040	0.050	0.063
1/32	.00070	.00074	.00079			
1/16	.00125	.00129	.00135	.00140	.00148	.00158
3/32	.00179	.00183	.00188	.00195	.00202	.00212
1/8	.00234	.00238	.00243	.00249	.00257	.00267
5/32	.00288	.00292	.00297	.00304	.00311	.00321
3/16	.00342	.00347	.00552	.00358	.00366	.00376
7/32	.00397	.00401	.00406	.00412	.00420	.00430
1/4	.00451	.00455	.00461	.00467	.00475	.00485



Bend allowance (Z) = $(0.01743R + 0.0078T) \times$ (No. of degrees of bend)

T = thickness of metal

R = radius of bend

Z = bend allowance

$X = A - (R + T)$

$Y = B - (R + T)$

Total developed length = $X + Y + Z$

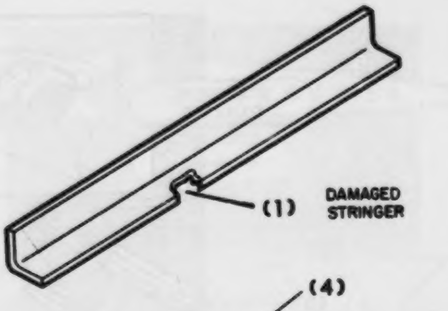
AM.445

Figure 4-2.—Computing bend allowance.

NOTE: The above repair is permissible when the damage does not exceed two-thirds of the width of one leg of the stringer, and is not over 12 inches in length. When the damage is of such length that a single reinforcement splice would involve an excessive amount of material and work, a repair by insertion should be made. (See figure 4-4.)

Spars and Their Repair

Spars (also called beams) are the main spanwise members of the wing, stabilizers, and other airfoils. They may run the entire length of the airfoil, or only part of the length. Spars are designed primarily to take bending loads imposed on the wing or other airfoil.



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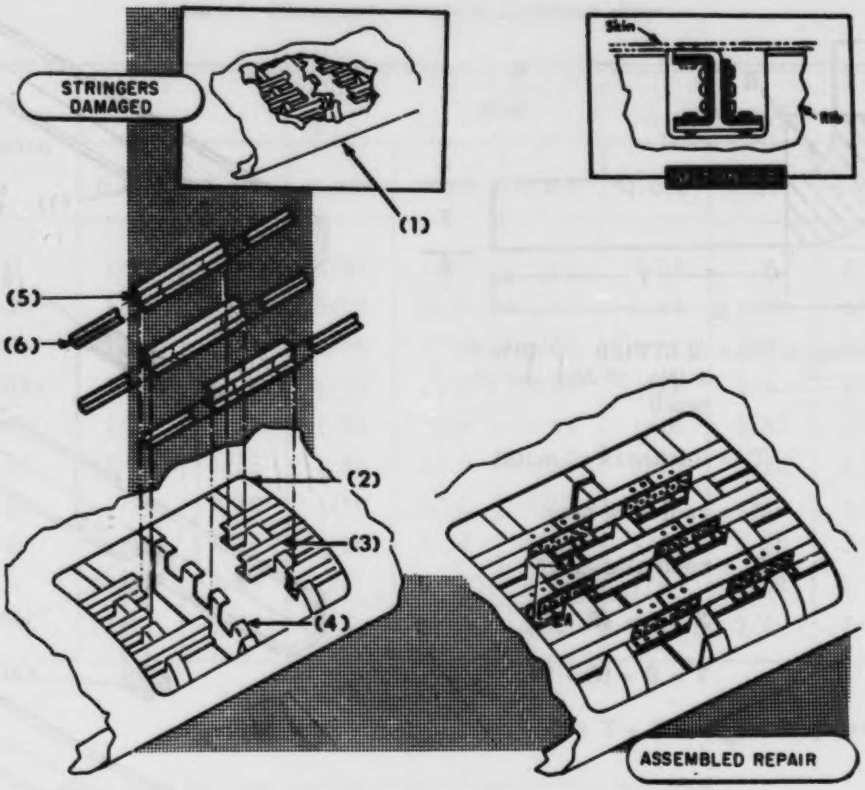
1. Damaged stringer.
2. Damaged cut out smooth with corner radii.
3. Filler splice.
4. Reinforcement splice.
5. Assembled repair.

Figure 4-3.—Stringer repair by patching.

The most common type of spar construction consists of extruded capstrips, a sheet metal web or plate, and vertical angle stiffeners. Since spars are very highly stressed members, their repair may not be permitted; and if permitted, must be made in strict accordance with instructions given in the Structural Repair Manual, using the best



AM.447

1. Damaged stringer
2. Damaged area cut out smooth with corner radii.
3. Damaged stringers smoothed and staggered.
4. Repaired rib as shown in figure 4-7.
5. Stringer insertions.
6. Splice angles or reinforcements
7. Assembled repair.

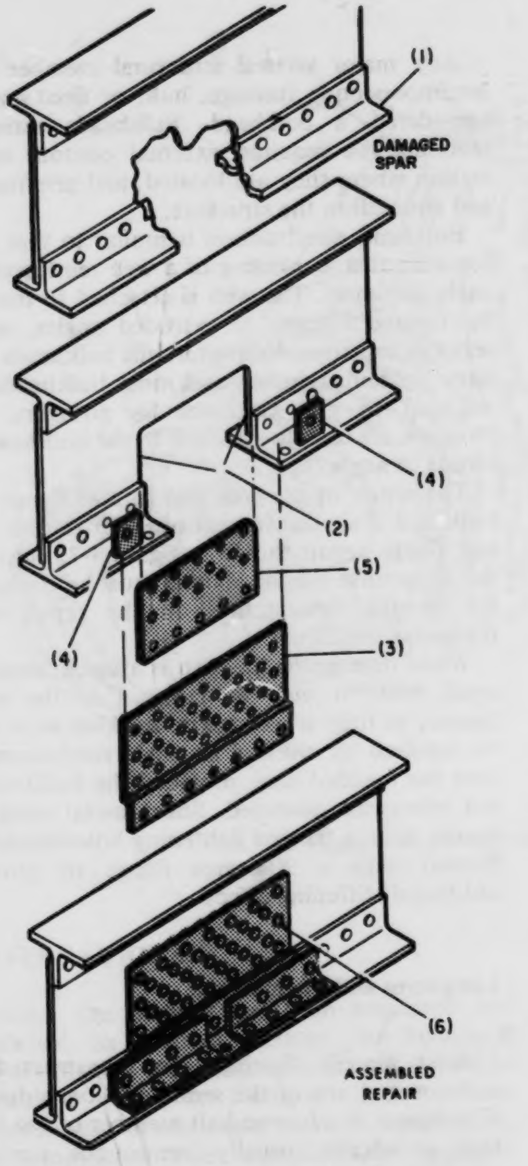
Figure 4-4.—Stringer repair by insertion.

possible workmanship. Figure 4-5 illustrates a spar web repair by insertion.

Ribs and Their Repair

Ribs are the principal chordwise structural members in the wings, stabilizers, and other airfoils. Ribs serve as formers for the airfoil, giving it shape and rigidity, and also serve to transmit stresses from the skin to the spars. They are designed to resist both compression and shear loads.

There are three general types of rib construction, as shown in figure 4-6. The reinforced rib and the truss rib are both relatively heavy as compared to the former rib, and are located only at points where the greatest stresses are imposed. Former ribs are located at frequent intervals throughout the airfoil.



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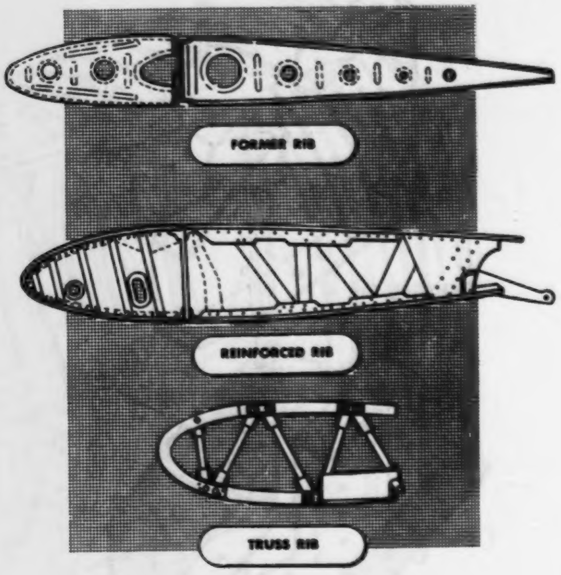
1. Damaged spar.
2. Damage cut out to a smooth straight edge with corner radii.
3. Joggled splice plate.
4. Two fillers of the same gage and material as splice plate.
5. Insertion.
6. Assembled repair.

Figure 4-5.–Spar repair by insertion.



AM.449

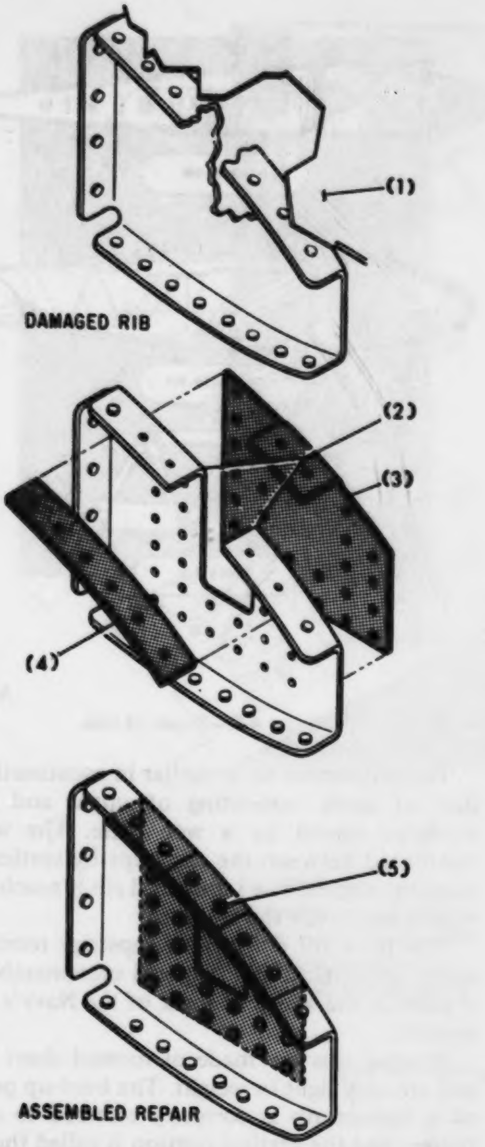
Figure 4-6.–Types of ribs.

The reinforced rib is similar in construction to that of spars, consisting of upper and lower capstrips joined by a web plate. The web is reinforced between the capstrips by vertical and diagonal angles. The reinforced rib is much more widely used than the truss rib.

The truss rib consists of capstrips reinforced solely by vertical and diagonal crossmembers. It is used in the wings of some of the Navy's larger aircraft.

Former ribs are made of formed sheet metal and are very light in weight. The bent-up portion of a former rib is correctly referred to as the flange, and the vertical portion is called the web. The web is generally constructed with lightening holes, with beads formed between the holes. The lightening holes lessen the weight of the rib without decreasing the strength. Rigidity of lightening hole areas is accomplished by flanging the edges of the lightening holes. The beads stiffen the web portion of the rib.

Rib repair by patching is illustrated in figure 4-7.



1. **Damaged rib.**
2. **Damaged area smooth.**
3. **Patch prepared so that it will fit flush with the flange of the rib.**
4. **Reinforcement strip.**
5. **Assembled repair.**

Figure 4-7.—Rib repair by patching.

Bulkheads and Their Repair

Any major vertical structural member of a semimonocoque fuselage, hull, or float may be considered a bulkhead. Bulkheads serve to maintain the required external contour at the station where they are located, and give rigidity and strength to the structure.

Bulkhead construction is similar to that used for wing ribs, consisting of a web reinforced by angle stiffeners. The web is attached to the skin by formed flanges or extruded angles, which serve as capstrips. Nonwatertight bulkheads may have lightening holes, and most bulkheads are cut out to give clearance for stringers. The stringers are usually attached to the bulkhead by means of angle clips.

The repair of the web and formed flange of a bulkhead is similar to that used for the rib web and flange repair shown in figure 4-7; however, the Structural Repair Manual must be consulted for specific information on the repair of a particular bulkhead.

When damage to the web is a crack, dent, or small hole, it may be repaired in the same manner as fully stressed skin. Buckled webs may be repaired by riveting an angle reinforcement over the buckled area, provided the bulkhead is not otherwise distorted. Sheet metal used for repairs near a flanged lightening hole should be formed with a 90-degree flange to provide additional stiffening effect.

Longerons and Their Repair

Most aircraft fuselages are constructed in sections and are of the semimonocoque design. A longeron is a fore-and-aft member of the fuselage or nacelle, usually continuous across a number of points of support, such as frames and bulkheads. The longerons along with the stringers are the major load carrying members and stiffeners. Figure 4-8 illustrates the location of the major members of a semimonocoque design forward fuselage. In case it becomes necessary to repair a longeron, review the section on stringer repair and follow the same procedure.

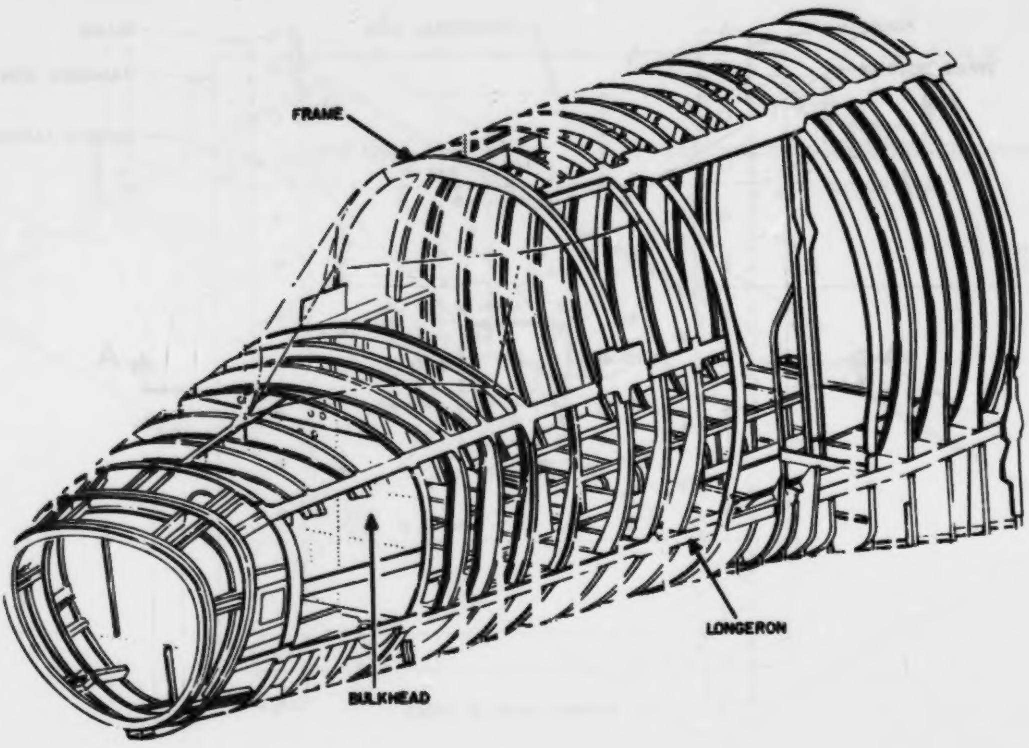


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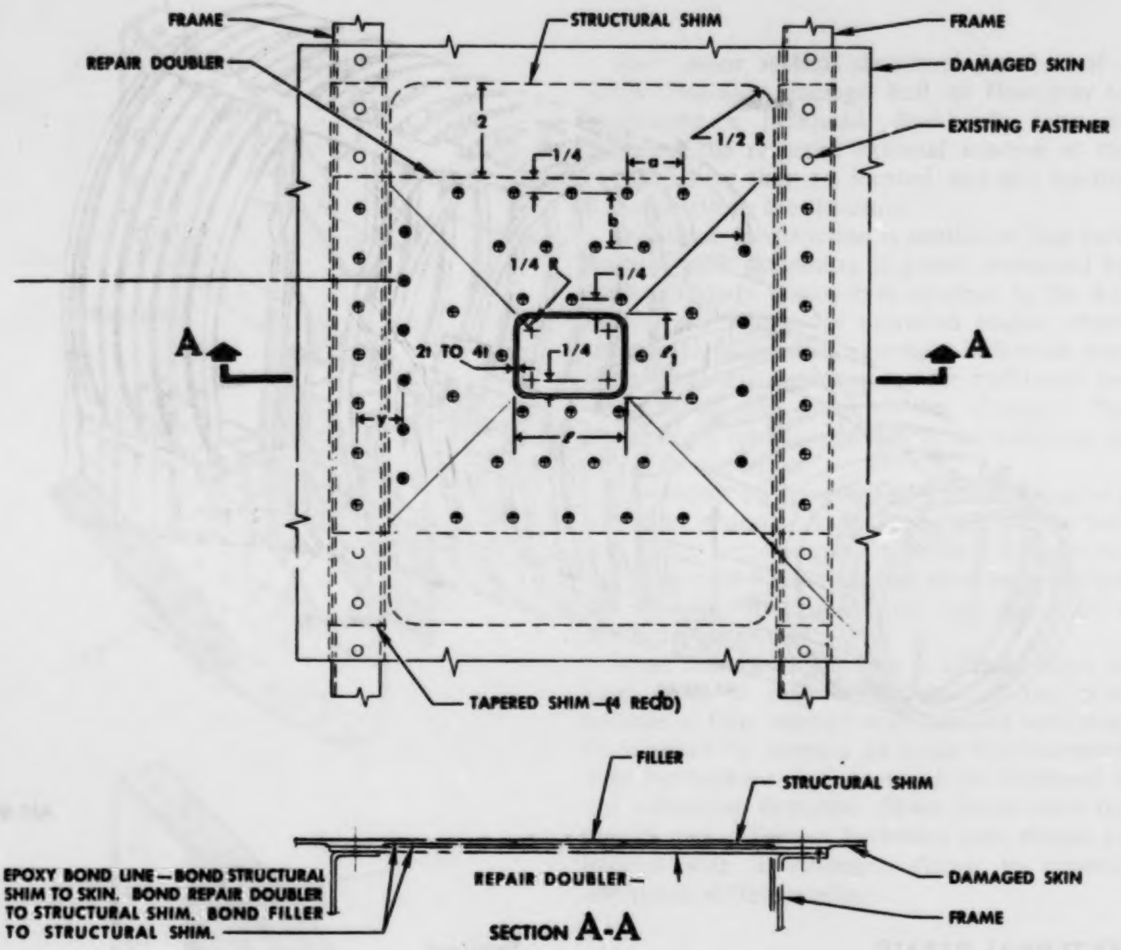
Figure 4-8.–Forward fuselage (semimonocoque).

EXTERNAL REPAIR

After the damage has been inspected and classified on external surfaces, the Structural Repair Manual for the specific aircraft should be consulted for the critical areas where aerodynamic smoothness must be maintained. An aerodynamic filler is available for negligible damage, steps, and gaps. In many sections the skin is Chem-Milled or machined. Chem-Mill is a process whereby the proper shape and size are obtained by a chemical acting on the metal; the proper shape and thickness of machined skin are obtained with the use of a shaper or milling machine. Some skin is manufactured with lands on the metal, which is a thicker portion of the skin where bulkheads and frames are attached.

Fuselage

Aircraft that are designed for high altitude performance, have one or more sections of the fuselage pressurized; and this factor must be taken into consideration when a repair is to be made. The fuselage is usually constructed from more than one type of metal, the most common type being aluminum alloy. On some aircraft the fuselage skin is Chem-Milled or machine tapered and highly stressed. Figure 4-9 illustrates a Chem-Milled skin repair on a pressurized fuselage section. The repair consists of a shim, doubler, and a filler. The damage is trimmed out and the inside corners are filed to a 1/4-inch radius. The replaced metal and rivets or other fasteners must be equal to or stronger than the


FRAME
STRUCTURAL SHIM
FRAME
REPAIR DOUBLER
DAMAGED SKIN
EXISTING FASTENER
2
1/2 R
1/4
a
b
1/4 R
1/4
2t TO 4t
1/4
ℓ
ℓ1
y
A
A
TAPERED SHIM—(4 REQD)
FILLER
STRUCTURAL SHIM
EPOXY BOND LINE—BOND STRUCTURAL SHIM TO SKIN. BOND REPAIR DOUBLER TO STRUCTURAL SHIM. BOND FILLER TO STRUCTURAL SHIM.
REPAIR DOUBLER—
DAMAGED SKIN
FRAME
SECTION A-A

AM.452

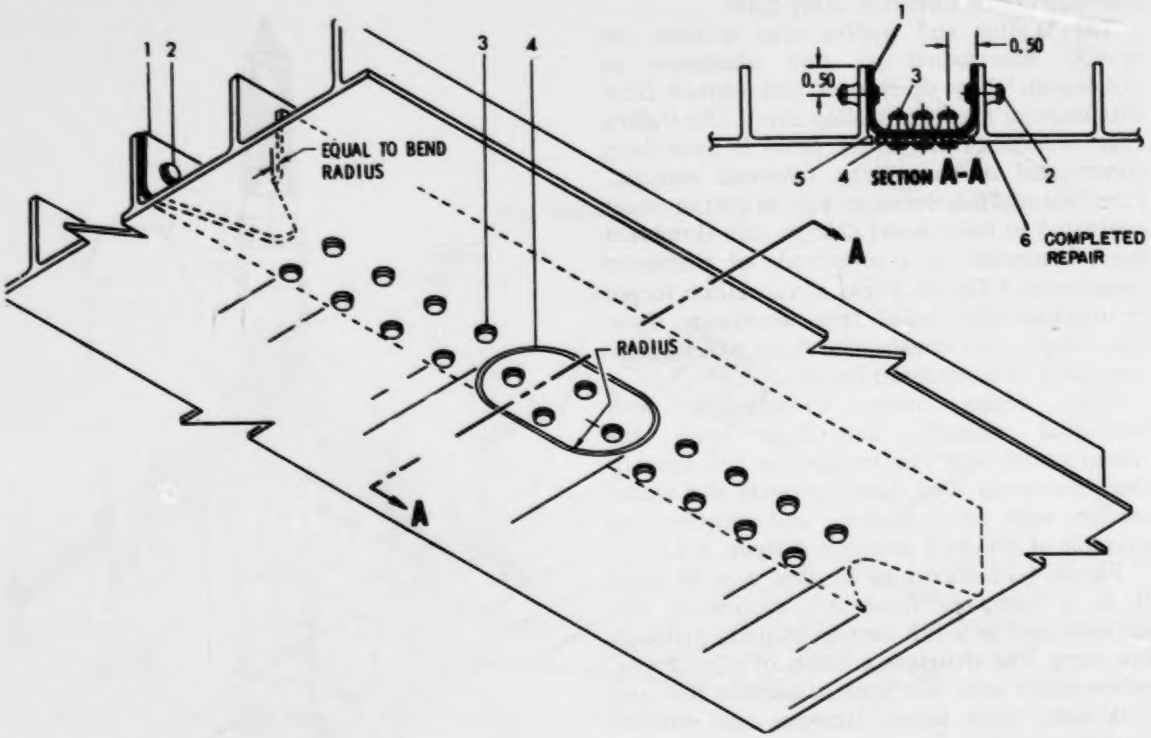
Figure 4-9.—Chem-Milled skin repair (fuselage pressurized).

original. The Structural Repair Manual should be consulted for fastener spacing, edge distance, and the repair procedure. During final assembly of the repair, the fabricated parts should be bonded together with an adhesive to insure that pressurization is maintained.

Wing

The wings on most modern aircraft are usually constructed in center sections and outer sections. These sections are designed in box form and are used as integral fuel cells. Some wings are constructed with Chem-Milled or machine tapered skin, tapered to various thicknesses depending on the place the beams or posts will be attached. Only minor repairs should be made on wings. If one is extensively damaged it should be replaced.

Figure 4-10 illustrates a skin repair on an outer wing section. It consists of a repair channel and a filler. The damage is trimmed and



AM.453

1. **Repair channel.**
2. **Riser fasteners.**
3. **Skin fasteners.**
4. **Filler.**
5. **Sealant.**
6. **Completed repair.**

Figure 4-10.–Outer wing section skin repair.

smoothed out for an oval filler, then the surrounding area is inspected for corrosion. The repair must be equal to or stronger than the original.

The Structural Repair Manual for the specific aircraft must be consulted for the correct fasteners, their spacing, the procedure for repair, and the proper sealant to be used.

REMOVAL AND INSTALLATION OF WINGS

In many instances damages to the wing are too extensive for repair by operating activities. In such cases the damaged wing must be removed and sent to a Depot maintenance facility, and a replacement wing installed on the aircraft.

Removal and installation of aircraft wings will vary with the design and construction of the wings.

DESIGN AND CONSTRUCTION OF WINGS

The wings of a modern high performance jet aircraft are normally constructed of aluminum alloy with front and rear spars or beams. These spars are connected by ribs formed from either aluminum or magnesium alloy sheet. The spanwise bending stress is carried by relatively thick center section tapered skins which are fabricated from aluminum alloy plate.

The leading and trailing edge sections are usually constructed of thin aluminum or magnesium alloy sheet over ribs formed from aluminum or magnesium alloy sheet. The trailing edge section of the outer panel is sometimes constructed of some type sandwich material. (This material may be either thin aluminum sheet laminated to balsa wood core or thin aluminum sheet laminated to a core made of aluminum honeycomb.) The wing-fold ribs are either forged or mechanically milled from aluminum alloy. The wingtips are constructed from either aluminum alloy or laminated Fiberglas.

Wing design varies considerably with individual aircraft, depending upon the manufacturer and the mission of the aircraft. One commonly used design consists of a center section with outer sections and wingtips. An example of this wing is shown in figure 4-11.

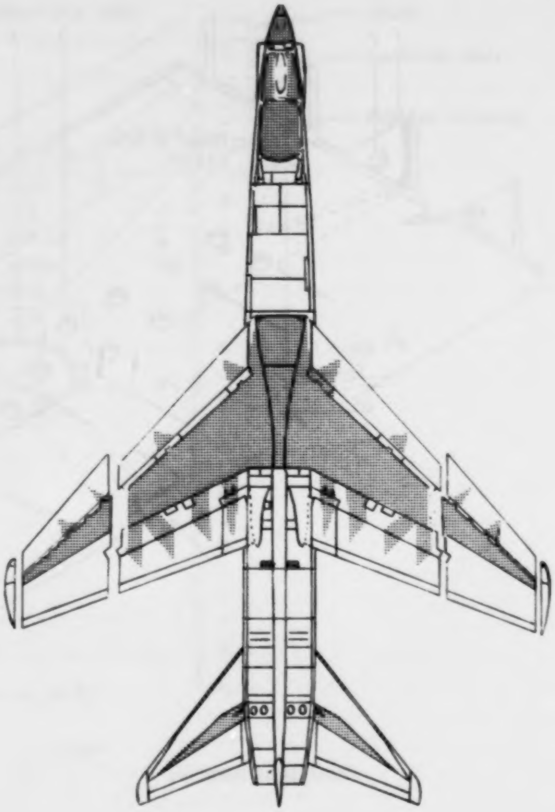
Figure 4-12 illustrates another type of wing. It is a complete removable section of the airframe and is a full cantilever, delta platform low wing. The structure consists of a front spar, intermediate spar, rear spar, chordwise ribs, and bulkheads, with lateral stringers and stressed flush-riveted skin. The major portion of the wing forms the integral fuel tank.

The wing shown in figure 4-13 is a thick skin, multispar, full cantilever, semimonocoque structure. The wing group consists of the center section and outer panels, leading and trailing edge flaps, ailerons, spoilers, and speed brakes. An integral fuel tank is located in the center section.

Basically, the internal structure consists of front, main, and rear spars, auxiliary spars, ribs, and stringers. This structure is covered with flush riveted tapered and constant gage aluminum alloy skin. Aluminum faced aluminum honeycomb core sandwich material is used in the construction of the trailing edge section of the outer panel.

PROCEDURE FOR REMOVAL AND INSTALLATION OF WINGS

Removal and installation of a wing is a major operation requiring experienced personnel and close supervision by a senior petty officer.



AM.454

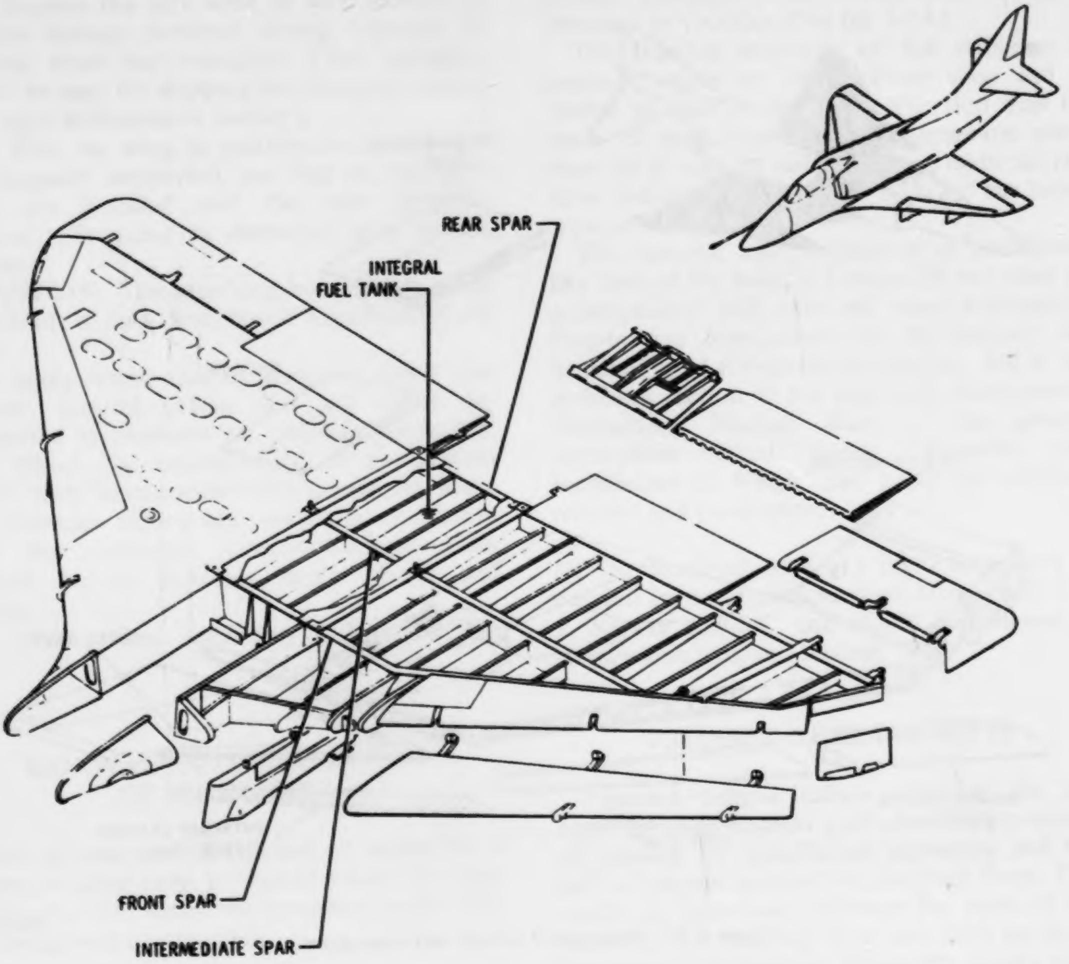
Figure 4-11.—Typical wing design.

The airframes section of the applicable Maintenance Instructions Manual should be read carefully before attempting to remove a wing. This manual will give step-by-step instructions for wing removal and installation. It is necessary to follow these instructions to prevent possible damage caused by failure to disconnect or connect units in the proper sequence.

Listed below are some general precautions which should be observed in removing and installing a wing or wing section.

Removal precautions:

1. The aircraft should be placed in a hangar or other area protected from the wind.



AM.455

Figure 4-12.—Delta wing.

2. Make certain all the necessary equipment is available and at hand. (A list of the necessary special tools and equipment will be found in the applicable Maintenance Instructions Manual.)

3. Insure that sufficient manpower is at hand for proper handling.

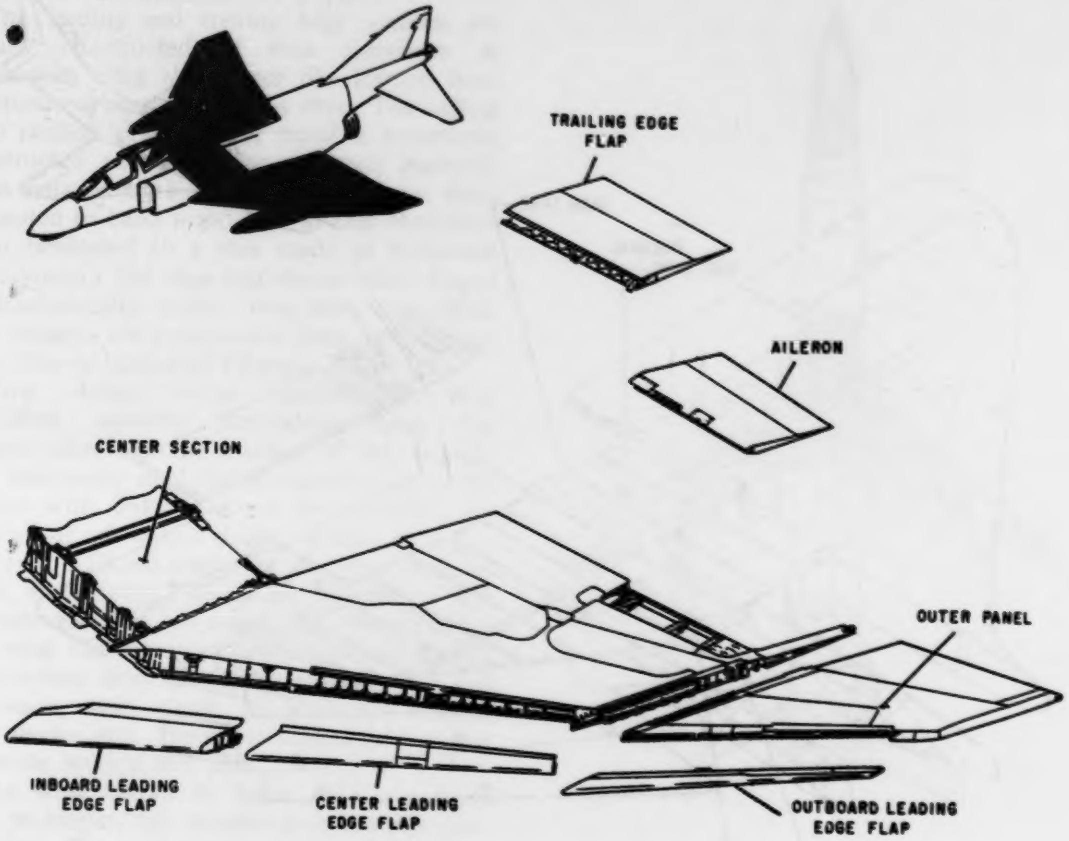
4. See that all screws, bolts, and other removed fasteners are placed in containers and properly marked to prevent loss.

5. Removed fairing should be marked and stowed in a safe place.

6. In disconnecting tubing, electrical connectors, control cables, bonding wires, and the like, see that the instructions given in the aircraft Maintenance Instructions Manual are carried out.

7. Make certain that all disconnected tubing is capped.

8. If hoisting equipment is to be used, be sure that it is in good condition and that a qualified operator is available. Also insure that the hoist fittings are properly installed. Some wings will



AM.456

Figure 4-13.—Wing center section and outer panel.

not balance at their hoist fittings, making it necessary to attach guide ropes to keep the wing steady after it is disconnected from the aircraft.

9. Before attempting to remove any structural bolts, make certain that the wing is properly supported, with all loads removed from the fittings. A mallet and brass drift pin may be used in removing these bolts.

10. After the wing is removed from the aircraft, all fittings, connections and unremoved structural members should be inspected for secondary damage before installing the new wing or wing section. (Secondary damage is damage to adjacent structure which may have resulted from the transmission of the shock or load which caused the primary damage.)

11. Before installing the new wing, advantage should be taken of improved accessibility to inspect for and repair corrosion damage and renew preservative coatings in heretofore inaccessible areas.

The petty officer in charge should see that the following general precautions are taken in installing a wing or wing section:

1. Check the identification tag of the new assembly, making sure it is the correct replacement unit.

2. See that extreme care is taken in removing it from the container, thus preventing any possible damage.

3. Inspect the new wing or wing section for possible damage incurred during shipment or removal from the container. (The container should be used for shipping the damaged wing to the Depot maintenance facility.)

4. With the wing in position for installation and properly supported, see that all structural bolts are installed and the nuts properly torqued. (Torquing is discussed later in the chapter.)

CAUTION: The attaching bolt should never be forced; if they bind, check alignment of the wing.

5. Make certain that all tubing, electrical connectors, control cables, and any other disconnected mechanisms are properly connected.

6. Check the operation of all mechanisms which were disconnected during removal. Make the necessary rigging adjustments in accordance with the applicable Maintenance Instructions Manual before installing access doors and fairings.

7. Make a final inspection of the completed job.

REMOVAL AND INSTALLATION OF STABILIZERS

The removal and installation of stabilizers is similar in most cases to that of wings and wing panels. As with wings, the procedure varies with the design and construction.

DESIGN AND CONSTRUCTION OF STABILIZERS

On many aircraft the horizontal stabilizer is a movable airfoil, controllable from the cockpit. On some of these aircraft it is used in conjunction with the elevators to maintain longitudinal control at sonic speeds where the elevators have a tendency to lose their effectiveness. On other aircraft the movable horizontal stabilizer serves the dual purpose of elevators and stabilizer. On some aircraft it is referred to as a stabilator.

One aircraft in the fleet has an empennage or tail group which consists of all-movable horizontal stabilizers and a single all-movable vertical stabilizer. This aircraft does not have elevators or a rudder. (See fig. 4-14.)

The internal structure of the stabilizer is generally made up of aluminum alloy and is similar to that of the wing. The skin may be made of aluminum alloy or magnesium alloy sheet or it may be sandwich type material, the latter being widely used on many of the latest types of aircraft.

The removal and installation of stabilizers, like that of the wing, is a major job and must be accomplished with care and close supervision. Step-by-step instructions for the removal and installation of stabilizers are also included in the airframes section of the applicable Maintenance Instructions Manual. Many of the general precautions listed under "Removal and Installation of Wings" also apply to stabilizer removal and installation.

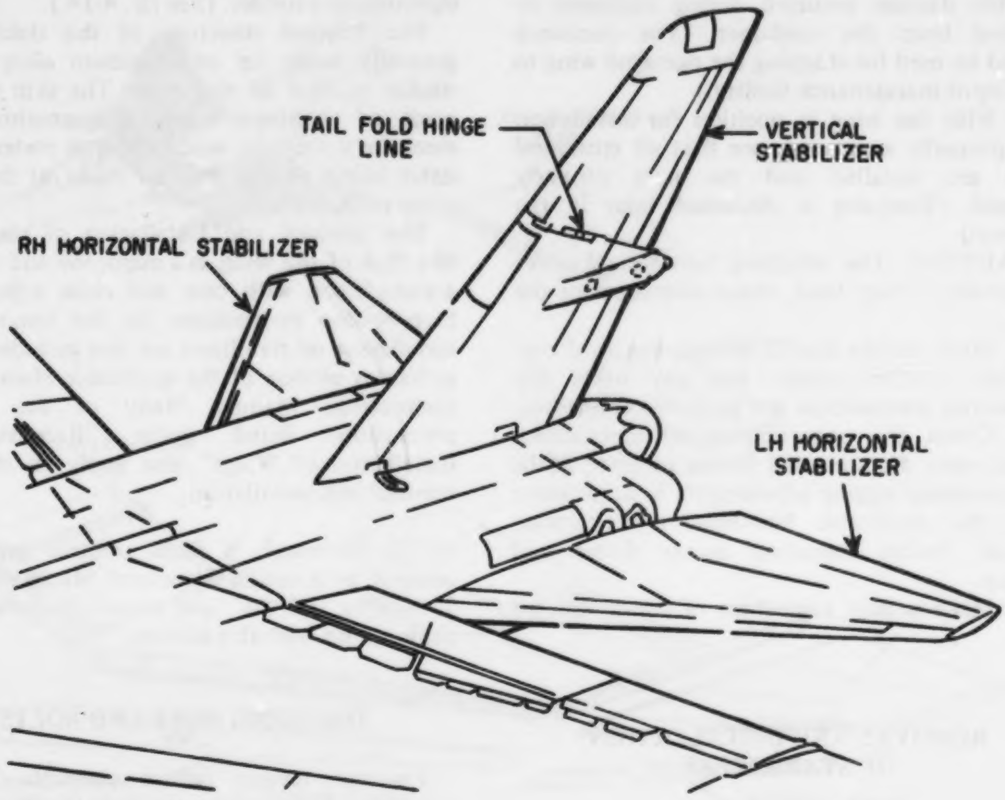
NOTE: Removal of flight control surfaces is covered in Aviation Structural Mechanic S 3 & 2, NavTra 10308-C, and should be reviewed in conjunction with this section.

TORQUING NUTS AND BOLTS

Fastener fatigue failure accounts for the majority of all fastener problems. Fatigue breaks are caused by insufficient tightening and the lack of proper preload or clamping force. This results in movement between the parts of the assembly and bending back and forth or cyclic stressing of the fastener. Eventually, cracks form at the high stress points, and these cracks will progress to the point where the fastener can no longer support its designed load. At this point the fastener fails with varying consequences.

In order for the nut to properly load the bolt and prevent premature failure, a designated amount of torque must be applied. Proper torque, in addition to distributing the stresses applied to each fastener safely throughout the structure, will also reduce the possibility of the fastener loosening in service.

The correct torque to apply when tightening an assembly is based on many variables. The fastener is subjected to two stresses when it is tightened–torsion and tension. Tension is the desired stress, while torsion is the necessary evil



AM.457

Figure 4-14.—Empennage design.

caused by friction. A large percentage of applied torque is utilized to overcome this friction, yet only tension remains after tightening.

The recommended torque values provided in table 4-3 have been established for average dry, cadmium-plated nuts for both the fine and coarse thread series of nuts. Thread surface variations such as paint, lubrication, hardening, plating, thread distortion, etc., may alter these values considerably. The torque values must be followed unless the Maintenance Instructions Manual or Structural Repair Manual for the specific aircraft requires a specific torque for a given nut. Torque values vary slightly with manufacturers. When the torque values are included in a technical manual for a specific end item, be it aircraft or component, these values take precedence over the standard torque values provided in the Structural Hardware Technical Manual, NavAir 01-2 A-8.

Separate torque tables and torquing considerations are provided in NavAir 01-1A-8 for the large variety of nuts, bolts, screws, etc., utilized in aircraft construction. The AMS supervising major assembly removal and installation should utilize this manual when specific torque values are not provided as a part of the removal/replacement instructions.

Table 4-3.—Recommended torque values (inch-pounds)

CAUTION

THE FOLLOWING TORQUE VALUES ARE DERIVED FROM OIL FREE CADMIUM PLATED THREADS.

	TORQUE LIMITS RECOMMENDED FOR INSTALLATION (BOLTS LOADED PRIMARILY IN SHEAR)		MAXIMUM ALLOWABLE TIGHTENING TORQUE LIMITS	
Tap Size	Tension type nuts MS20365 and AN310 (40,000 PSI in bolts)	Shear type nuts MS20364 and AN320 (24,000 PSI in bolts)	Nuts MS20365 and AN310 (90,000 PSI in bolts)	Nuts MS20364 and AN320 (54,000 PSI in bolts)
		FINE THREAD SERIES		
8-36	12-15	7-9	20	17
10-32	20-25	12-15	40	25
1/4-28	50-70	30-40	100	60
5/16-24	100-140	60-85	225	140
3/8-24	160-190	95-110	390	240
7/16-20	450-500	270-300	840	500
1/2-20	480-690	290-410	1100	660
9/16-18	800-1000	480-600	1600	960
5/8-18	1100-1300	600-780	2400	1400
3/4-16	2300-2500	1300-1500	5000	3000
7/8-14	2500-3000	1500-1800	7000	4200
1-14	3700-5500	2200-3300*	10,000	6000
1-1/8-12	5000-7000	3000-4200*	15,000	9000
1-1/4-12	9000-11,000	5400-6600*	25,000	15,000
		COARSE THREAD SERIES		
8-32	12-15	7-9	20	12
10-24	20-25	12-15	35	21
1/4-20	40-50	25-30	75	45
5/16-18	80-90	48-55	160	100
3/8-16	160-185	95-100	275	170
7/16-14	235-255	140-155	475	280
1/2-13	400-480	240-290	880	520
9/16-12	500-700	300-420	1100	650
5/8-11	700-900	420-540	1500	900
3/4-10	1150-1600	700-950	2500	1500
7/8-9	2200-3000	1300-1800	4600	2700

The above torque values may be used for all cadmium-plated steel nuts of the fine or coarse thread series which have approximately equal number of threads and equal face bearing areas.

***Estimated corresponding values.**

The following rules apply for correct use of table 4-3:

1. To obtain values in foot-pounds, divide-inch-pound values by 12.
2. Do not lubricate nuts or bolts except for corrosion-resistant steel parts or where specifically instructed to do so.
3. Always tighten by rotating the nut first if possible. When space considerations make it necessary to tighten the fastener by rotating the bolthead, approach the high side of the indicated torque range. Do not exceed the maximum allowable torque value.
4. Maximum torque ranges should be used only when materials and surfaces being joined are of sufficient thickness, area, and strength to resist breaking, warping, or other damage.
5. For corrosion-resisting steel nuts, use the torque values given for shear type nuts.
6. The use of any type of drive-end extension on a torque wrench (fig. 4-15) changes the dial reading required to obtain the actual values indicated in the torque range tables. When using a drive-end extension, the torque wrench reading must be computed using the following formula:

$$S = \frac{T \times L_a}{L_a + E_a}$$

S equals handle setting or reading
T equals torque applied at end of adapter
L_a equals length of handle in inches
E_a equals length of extension in inches

For example, if it is desired to exert 100 inch-pounds at the end of the wrench and extension, when L_a equals 12 inches and E_a equals 6 inches, it is possible to determine the handle setting by making the following calculation:

$$S = \frac{100 \times 12}{(12 + 6)}$$

$$S = \frac{1200}{18}$$

$$S = 66.6 \text{ inch-pounds}$$

Whenever possible, attach the extension in line with the torque wrench. When necessary to attach the extension at an angle to the torque wrench as shown in figure 4-15, the effective length of the assembly will be $L_a + E_b$ as shown in the figure. In this instance, length E_b must be substituted for length E_a in the formula.

NOTE: It is not advisable to use a handle extension on a flexible beam type torque wrench at any time. A handle extension alone has no effect on the reading of other types. The use of a drive-end extension on any type of torque wrench makes use of the formula necessary. When the formula has been used, force must be applied to the handle of the torque wrench at the point from which the measurements were taken. If this is not done, the torque obtained will be in error.

AIRFRAME ALIGNMENT

Alignment of the airframe structure is nothing more than the position relationship of each major component–the wing group, tail group, and fuselage group–to the other. The alignment of the airframe is important since it is directly related to the aerodynamic performance of the aircraft. Misalignment may affect the flight characteristics of the aircraft and consequently the efficiency of the pilot-aircraft combination.

For this reason and for purposes of determining if any hidden structural failures exist, an alignment check should be performed when an aircraft has encountered excessive G's in flight, when a hard landing has been experienced, or when the aircraft has been subjected to extensive damage.

The need for an alignment check after extensive damage is rather apparent; however, this is not necessarily so in situations where aircraft exceeds the G design limit or where a hard landing has been experienced. The alignment check under these conditions may bring to light damage which might otherwise go unnoticed.

LEVELING METHODS

Prior to making an alignment check it is necessary to level the aircraft both laterally and longitudinally. This may be accomplished by

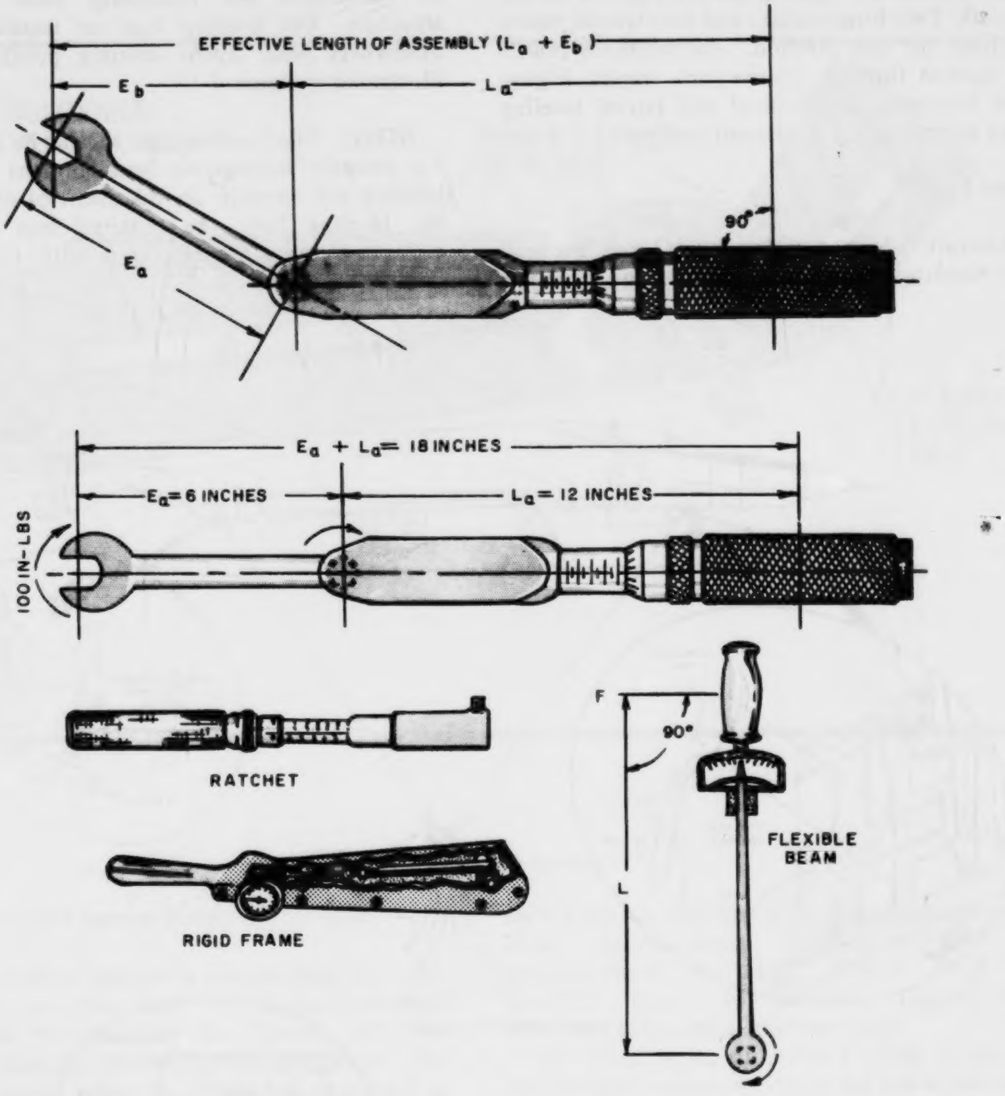

EFFECTIVE LENGTH OF ASSEMBLY (L_a + E_b)
E_b
L_a
90°
E_a
E_a + L_a = 18 INCHES
E_a = 6 INCHES
L_a = 12 INCHES
100 IN-LBS
RATCHET
RIGID FRAME
F
90°
FLEXIBLE BEAM
L
AM.1079

Figure 4-15.—Torque wrenches.

using the transit, spirit level, or plumb bob and datum plate method.

When leveling an aircraft for an alignment check, the aircraft should be inside a hangar where air currents will not interfere with the accuracy of the alignment readings. Jacks should be used to control the attitude of the aircraft during the check.

The method of leveling specified by the manufacturer in the applicable Structural Repair Manual should always be used.

Transit

The transit method is preferred because of the accuracy which is obtained. Transit leveling is accomplished by sighting specified points on the aircraft. Two longitudinal and two lateral points are used for this method. The reference points are sighted through a surveyor's transit. Figure 4-16 illustrates longitudinal and lateral leveling of an aircraft using the transit method.

Spirit Level

Aircraft which use the spirit level method have leveling lugs either built into the structure or provisions for mounting them on the structure. The leveling lugs are usually in the nosewheel well. Spirit leveling provisions are illustrated in figure 4-17.

NOTE: The leveling lugs should be inspected for possible damage or misalignment prior to leveling the aircraft. In the event of damage to the leveling lugs, the repaired lugs must be calibrated by cross reference with the transit leveling method.

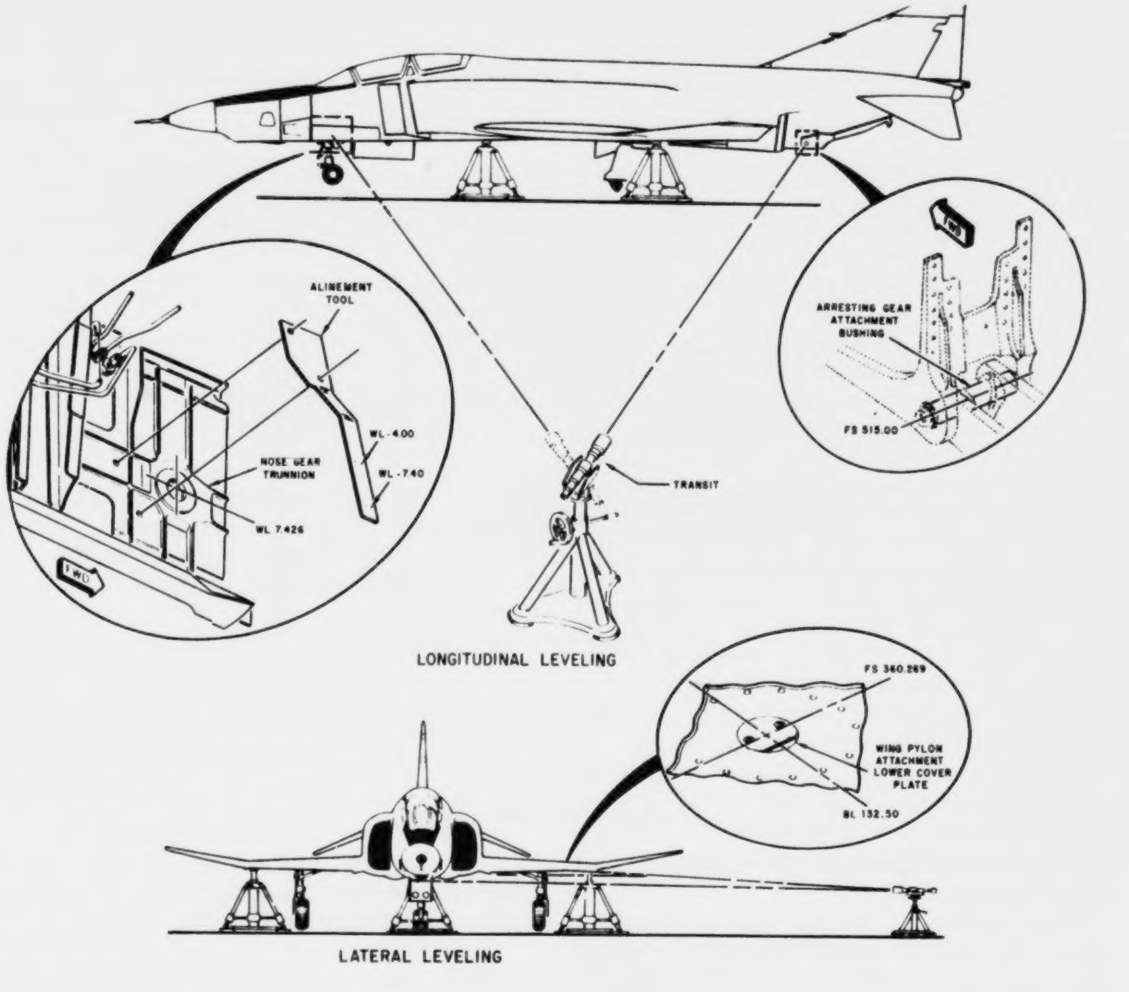

ALINEMENT TOOL
NOSE GEAR TRUNNION
WL 7.426
WL -4.00
WL -7.40
FWD
TRANSIT
ARRESTING GEAR ATTACHMENT BUSHING
FS 515.00
LONGITUDINAL LEVELING
FS 360.269
WING PYLON ATTACHMENT LOWER COVER PLATE
BL 132.50
LATERAL LEVELING
AM.459

Figure 4-16.—Transit leveling.

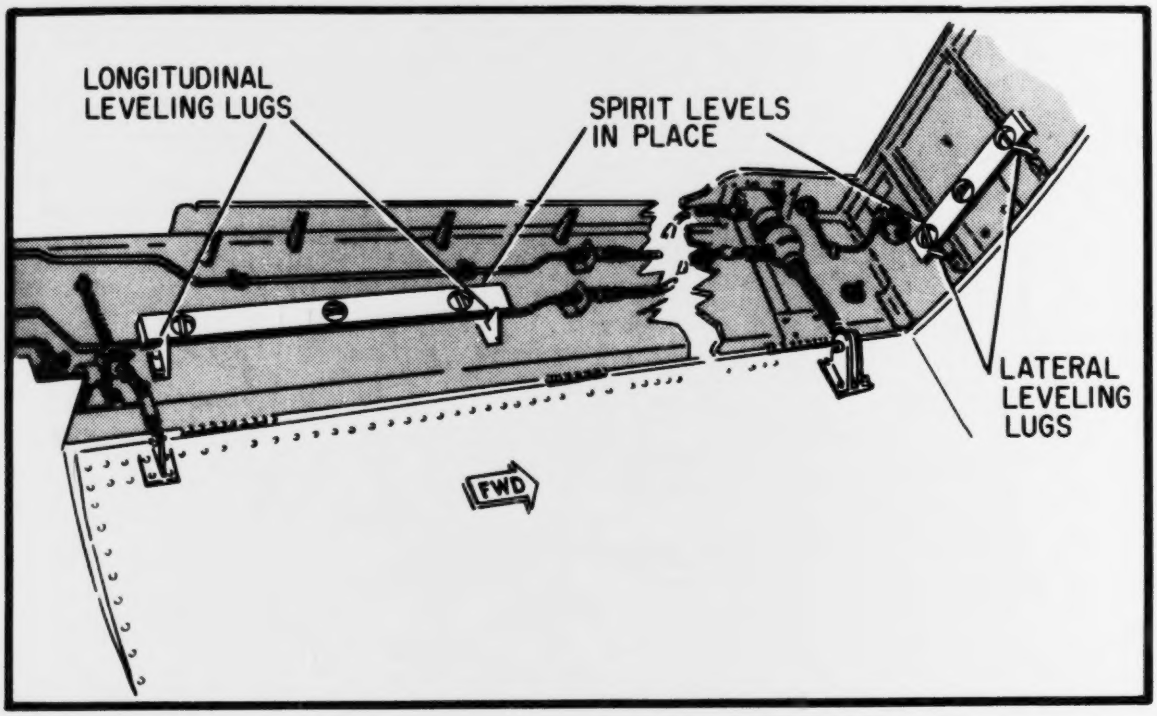


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Figure 4-17.–Spirit leveling.

Plumb Bob and Datum Plate

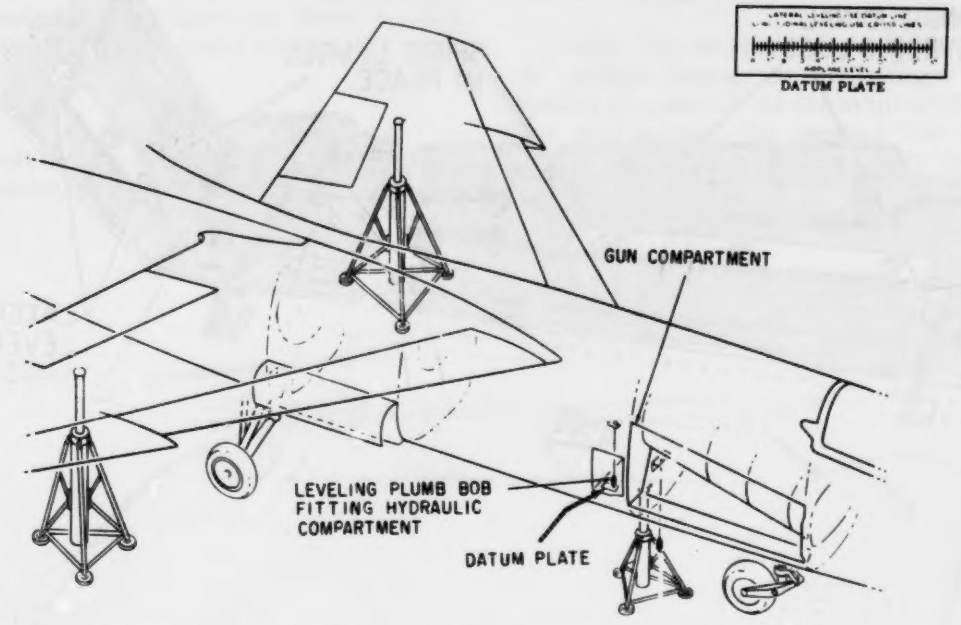
This method utilizes a datum plate or scale mounted on the deck of a compartment. Provisions for hanging the plumb bob are located directly above the datum plate. The aircraft is level when the plumb bob pointer is at 0° on the datum plate. Figure 4-18 illustrates the plumb bob and datum plate method of aircraft leveling.

ALIGNMENT CHECK

The alignment or symmetry check is made after the aircraft has been leveled. This check is made by measuring the distance between certain points on the aircraft. These points are selected because they are relatively static and because their location will best reflect any misalignment. Most manufacturers recommend that the measurements be taken directly from one specified point to another. Figure 4-19 illustrates this type alignment check.

On other types of aircraft, drop points are provided at various locations for use in checking the alignment. Plumb bobs are dropped from each of these points to the reference plane (floor) so that the pattern for measurement may be described. When using this method, the elevation check dimensions are measured from the drop points to the reference plane, in this case the floor. The horizontal check dimensions are measured from one point (described by the plumb bob), along the reference plane (floor) to another point.

If the alignment check measurements exceed the tolerances listed in the aircraft Structural



AM.461

Figure 4-18.—Plumb bob and datum plate leveling.

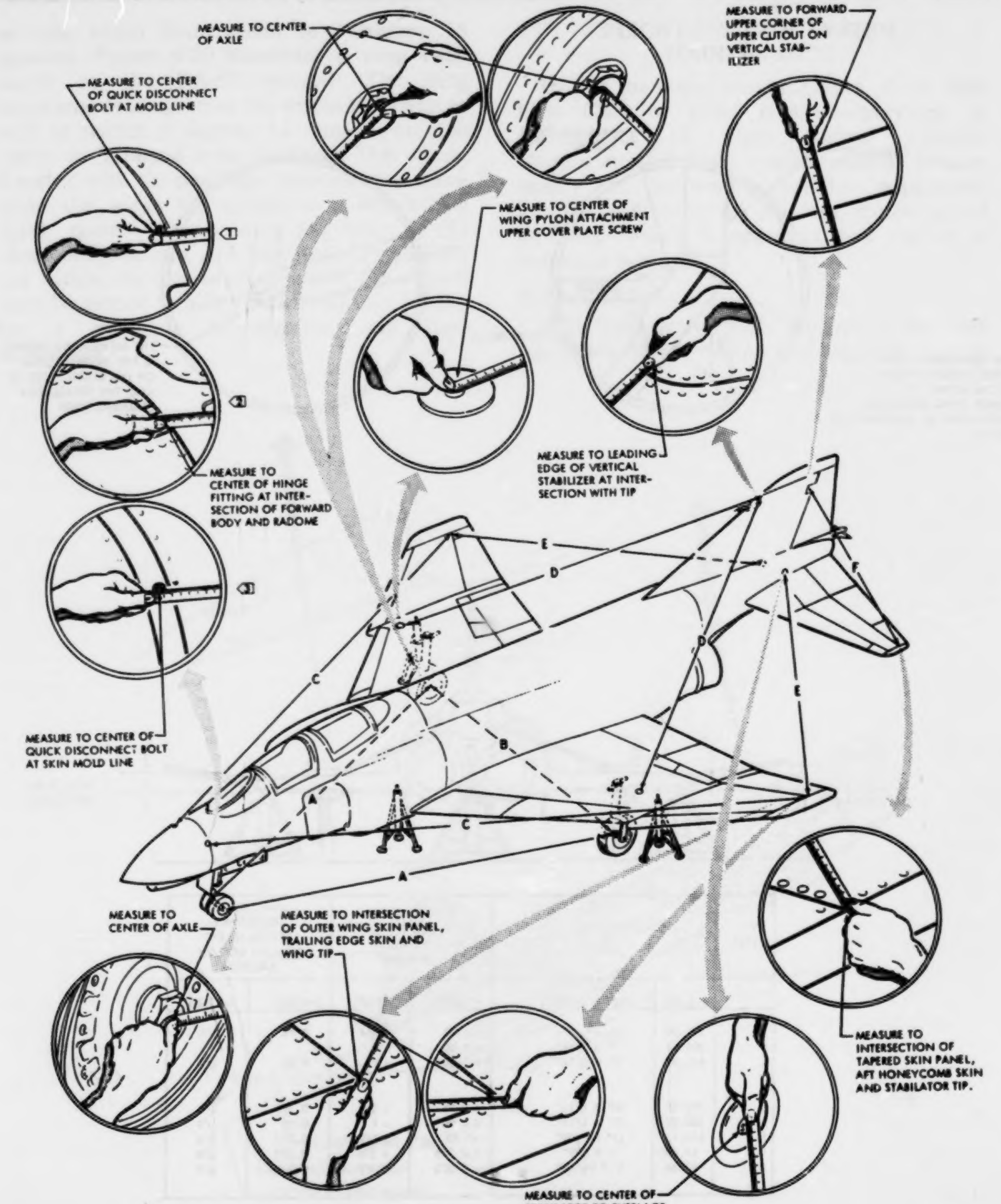
Repair Manual, the aircraft must be considered nonairworthy until a special disposition can be made by higher authority.

Wing Twist Check

With the aircraft leveled and the wings folded, it is possible to check the wings for twist. One checkpoint is provided on each wing. Clinometer readings taken at these points, when compared to the fuselage longitudinal clinometer readings, will enable the repairman to ascertain the condition of each wing. This is possible because there is a definite relationship between the fuselage longitudinal and wing reference lines. To perform a wing twist check, proceed as follows:

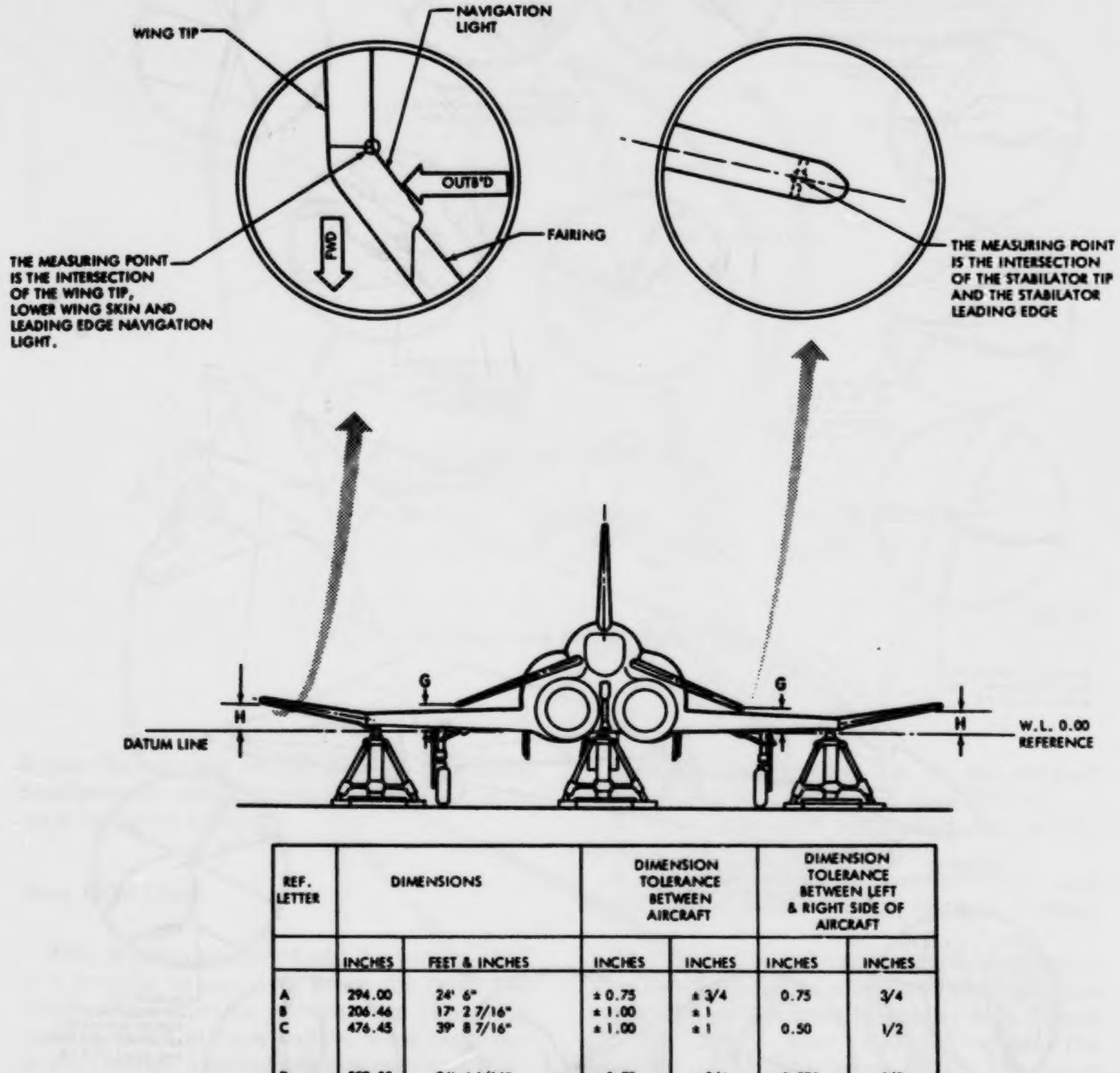
1. Fold wings and level aircraft laterally.
2. Install the leveling bar in the forward lockpin holes of the outboard panel fold rib.
3. Turn rod until the milled flat at the forward end is straight up.
4. Set the clinometer on the "flat" and record reading when dial has stopped rotating.

The right- and left-hand wing readings must be within 0 degree, 12 minutes of each other for acceptable aerodynamic tolerances with respect to twist. They must also fall within the following upper and lower limits. The lower limit is established by subtracting 0 degree, 20 minutes from the longitudinal reading and the upper limit is established by adding 0 degree, 40 minutes to the longitudinal reading taken in the auxiliary wheel well. For example, if the lognitudinal reading was 1 degree, 35 minutes, the lower limit would be 1 degree, 15 minutes


MEASURE TO CENTER OF AXLE
MEASURE TO FORWARD UPPER CORNER OF UPPER CUTOUT ON VERTICAL STABILIZER
MEASURE TO CENTER OF QUICK DISCONNECT BOLT AT MOLD LINE
1
MEASURE TO CENTER OF WING PYLON ATTACHMENT UPPER COVER PLATE SCREW
2
MEASURE TO CENTER OF HINGE FITTING AT INTERSECTION OF FORWARD BODY AND RADOME
MEASURE TO LEADING EDGE OF VERTICAL STABILIZER AT INTERSECTION WITH TIP
3
E
D
F
C
D
E
B
A
C
A
MEASURE TO CENTER OF QUICK DISCONNECT BOLT AT SKIN MOLD LINE
MEASURE TO CENTER OF AXLE
MEASURE TO INTERSECTION OF OUTER WING SKIN PANEL, TRAILING EDGE SKIN AND WING TIP
MEASURE TO INTERSECTION OF TAPERED SKIN PANEL, AFT HONEYCOMB SKIN AND STABILATOR TIP.
MEASURE TO CENTER OF STABILATOR TO FUSELAGE COVER PLATE SCREW

AM.462

Figure 4-19.–(A) Aircraft alignment data.


WING TIP
NAVIGATION LIGHT
OUTB'D
FWD
FAIRING
THE MEASURING POINT IS THE INTERSECTION OF THE WING TIP, LOWER WING SKIN AND LEADING EDGE NAVIGATION LIGHT.
THE MEASURING POINT IS THE INTERSECTION OF THE STABILATOR TIP AND THE STABILATOR LEADING EDGE
G
G
H
H
DATUM LINE
W.L. 0.00 REFERENCE

REF. LETTER	DIMENSIONS		DIMENSION TOLERANCE BETWEEN AIRCRAFT		DIMENSION TOLERANCE BETWEEN LEFT & RIGHT SIDE OF AIRCRAFT	
	INCHES	FEET & INCHES	INCHES	INCHES	INCHES	INCHES
A	294.00	24' 6"	± 0.75	± 3/4	0.75	3/4
B	206.46	17' 2 7/16"	± 1.00	± 1		
C	476.45	39' 8 7/16"	± 1.00	± 1	0.50	1/2
D	292.05	24' 4 1/16"	± 0.75	± 3/4	0.375	3/8
E	260.08	21' 8 1/16"	± 1.00	± 1	0.50	1/2
F	143.15	11' 11 1/8"	±0.50	± 1/2	0.375	3/8
G	17.403	1' 5 3/8"	± 0.375	± 3/8	0.375	3/8
H	19.66	1' 7 11/16"	± 0.375	± 3/8	0.375	3/8

AM.463

Figure 4-19.—(B) Aircraft alignment data and measurement chart.

and the upper limit would be 2 degrees, 15 minutes. Figure 4-20 illustrates a wing twist check on the RA-5C aircraft. The wing clinometer readings must fall within this range as well as within 0 degree, 12 minutes of each (right- to left-hand wing readings). This check, together with the steel tape measurements taken when the wings are spread, is a satisfactory check against wing bending and twist. If the clinometer readings and tape measurements are not within the tolerances specified, the aircraft must be ferried to a Depot maintenance facility for a complete investigation and final disposition.

FLIGHT CONTROL SYSTEM MAINTENANCE

One of the major responsibilities of the AMS First Class or Chief is the supervision of maintenance of flight control systems. Maintenance of flight control systems consists mainly of performing routine inspections, locating and correcting troubles, removing and replacing system components, and rigging of individual systems.

INSPECTIONS

With high performance aircraft, a thorough inspection of the various flight control systems

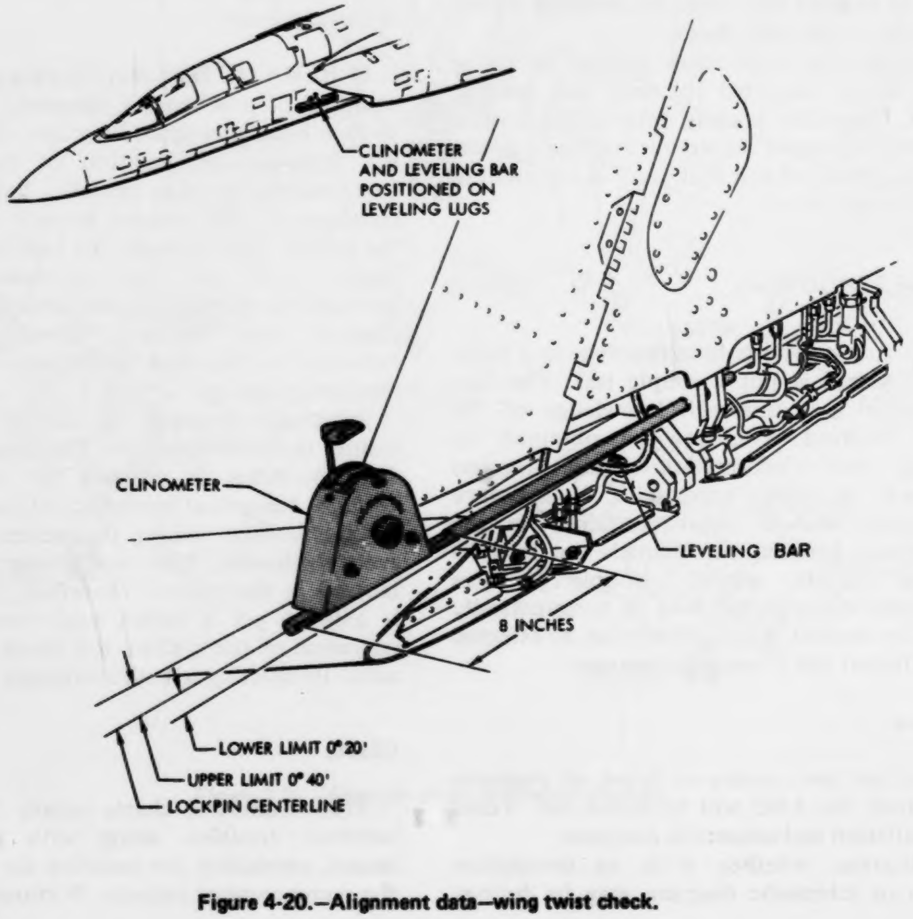

CLINOMETER AND LEVELING BAR POSITIONED ON LEVELING LUGS
CLINOMETER
LEVELING BAR
8 INCHES
LOWER LIMIT 0°20'
UPPER LIMIT 0°40'
LOCKPIN CENTERLINE
AM.464

Figure 4-20.–Alignment data–wing twist check.

is of paramount importance. Leading petty officers should be familiar with all inspection requirements and should stress the importance of thoroughly inspecting each system to each check-crew member.

On the preflight and daily inspections, particular attention should be given to checking each control surface for proper response to the cockpit control. Proper response means that the control surface and control linkage move smoothly and freely through their entire range of operation with no binding, unusual noises, or jerky action, and no free play. When any of these conditions exist, the trouble should be isolated and corrected at once.

In checking a system, all operational checks and tests should be made in the sequence outlined in the aircraft Maintenance Instructions Manual. If any malfunction is noted, the cause should be isolated and the fault corrected before proceeding to the next check.

Some calendar inspections require the entire linkage to be inspected for wear and possible damage. Therefore, leading petty officers must see that all necessary inspection doors and access plates are removed and that every component in the system is checked.

TROUBLESHOOTING

Correcting a reported malfunction in a flight control system is not a simple task. The first prerequisite is a thorough knowledge of the system involved. This can be obtained by studying the information and diagrams contained in the applicable Maintenance Instructions Manual. Also contained in the Maintenance Instructions Manuals are troubleshooting charts and/or trouble analysis procedures that can be used to systematically isolate the trouble so that repairs can be effected in an efficient and economical manner.

Diagrams

There are two classes or types of diagrams with which the AMS will be concerned. These are installation and schematic diagrams.

A diagram, whether it is an installation diagram or schematic diagram, may be defined as a graphic representation of an assembly or system, indicating the various parts and expressing the methods or principles of operation.

INSTALLATION DIAGRAM.–Figure 4-21 is an example of an installation diagram. This is a diagram of the elevator control torque tube assembly on the P-3A aircraft. It identifies each of the components in the assembly and shows their location within the aircraft on the principal view. Each letter (A, B, etc.) on the principal view refers to a detail view located elsewhere on the diagram. Each detail view is an enlarged drawing of a portion of the system.

Diagrams of this type are used extensively in all aircraft Maintenance Instructions Manuals and are invaluable to maintenance personnel in identifying and locating components and understanding the principle of operation of various systems.

SCHEMATIC DIAGRAMS.–Figure 4-22 is an example of a schematic diagram of a control surface booster system. Diagrams of this type do not indicate the location of the individual components in the aircraft, but do locate components with respect to each other within the system. For example, the bellcrank shown in figure 4-22 is not necessarily located immediately forward of the input quadrant. The diagram does indicate, however, that the bellcrank is connected to the input quadrant by dual cable linkage.

Schematic diagrams of this type are used mainly in troubleshooting. The simplicity of the diagram makes it possible for the AMS to visualize the actual movement of the mechanical linkage without tracing the movement through every bellcrank, idler arm, lever, pulley, and fairlead in the system. Therefore, the mechanic is able to get a better understanding of the operation of the system, and much time can be saved in locating a malfunctioning component.

Charts

Troubleshooting charts usually list the most common troubles, along with the probable causes, procedure for isolating the trouble, and the recommended remedy. Portions of a typical

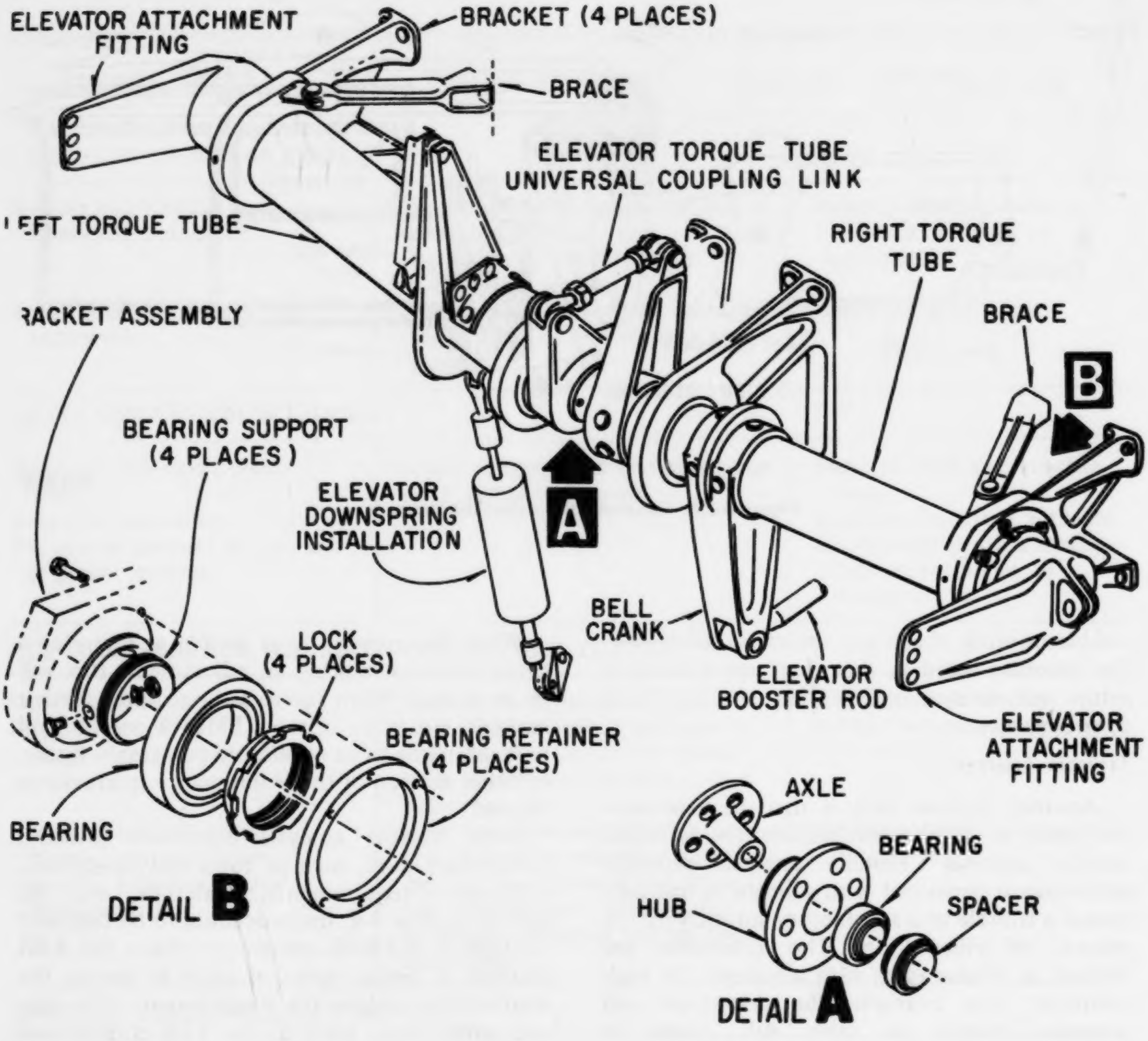
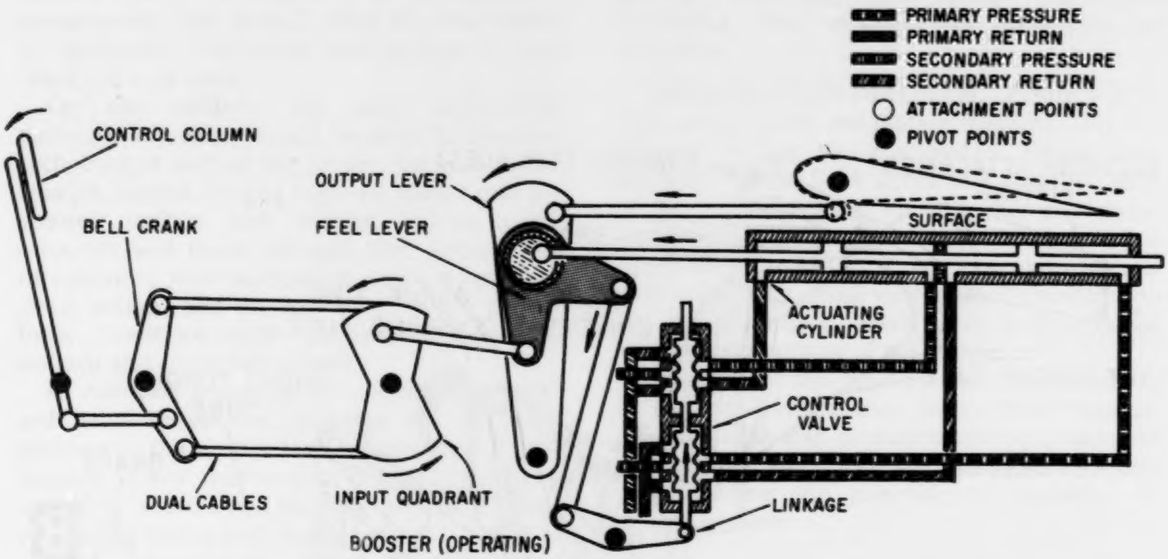

ELEVATOR ATTACHMENT FITTING
BRACKET (4 PLACES)
BRACE
ELEVATOR TORQUE TUBE UNIVERSAL COUPLING LINK
EFT TORQUE TUBE
RIGHT TORQUE TUBE
RACKET ASSEMBLY
BRACE
B
BEARING SUPPORT (4 PLACES)
ELEVATOR DOWNSPRING INSTALLATION
A
BELL CRANK
ELEVATOR BOOSTER ROD
ELEVATOR ATTACHMENT FITTING
LOCK (4 PLACES)
BEARING RETAINER (4 PLACES)
BEARING
DETAIL B
AXLE
BEARING
HUB
SPACER
DETAIL A
AM.466

Figure 4-21.–Example of an installation diagram.


PRIMARY PRESSURE
PRIMARY RETURN
SECONDARY PRESSURE
SECONDARY RETURN
○ ATTACHMENT POINTS
● PIVOT POINTS
CONTROL COLUMN
OUTPUT LEVER
BELL CRANK
FEEL LEVER
SURFACE
ACTUATING CYLINDER
CONTROL VALVE
DUAL CABLES
INPUT QUADRANT
LINKAGE
BOOSTER (OPERATING)

AM.465

Figure 4-22.—Example of a schematic diagram.

troubleshooting chart are shown in table 4-4. The troubles listed in this chart are general in nature and do not apply to any specific flight control system.

Trouble Analysis

Another method that is used to determine the cause of a reported malfunction is called trouble analysis. Trouble analysis provides maintenance personnel with a means to logically pursue a trouble to a satisfactory solution by the process of elimination. The symptoms are defined in tabular form with a remedy for each symptom. For example, the symptoms and remedies shown in table 4-5 relate to discrepancies occurring in an operational environment (in-flight or ground operation). (NOTE: Trouble analysis procedures to be followed in operational checkouts are also provided in Maintenance Instructions Manuals that use this method of determining the cause of malfunctions.)

When the remedy is as simple as replacing a component or making an adjustment, this will be so stated. When the remedy requires further analysis, the entry in the REMEDY column will be a reference to an applicable paragraph, figure, or other section of the Maintenance Instructions Manual.

Each trouble analysis procedure provides preliminary data, such as tools and equipment, manpower requirements, materials, etc. As shown in table 4-6, the procedure to be followed contains a NO-YES column to direct the AMS through a logical series of steps to isolate the malfunction. When the requirements of a step are satisfactory, refer to the YES column and perform the reference step. When the requirements of a step are not satisfactory, refer to the NO column and perform the referenced step. This method is used until the malfunction is isolated and corrected. Then the original checkout procedure must be performed to insure that the malfunction has been corrected.

Table 4-4.—Troubleshooting Chart

Probable Cause	Isolation Procedure	Remedy
CONTROLS CATCH OR BIND:		
Mechanical linkage or hydraulic actuators.	Disconnect valve operating rod on actuator. Move stick. If binding occurs, trouble is in mechanical linkage.	Rework interference or replace actuator as necessary.
Worn bearing in pulley or bellcrank.	Observe each pulley and bellcrank while stick is moved back and forth.	Replace faulty part.
JERKY OPERATION IN FLIGHT:		
Worn or undersize hinge bolts.	Remove hinge bolts and check for wear and proper size.	Replace with serviceable item.
Defective actuator.	....	Replace defective actuator.
Excessive amount of air in power system.	....	Move control stick through full travel about 15 times
CONTROL SURFACE WILL NOT ATTAIN FULL TRAVEL:		
Cable tension too low.	Check cable tension.	Rig cables correctly.
Stops improperly adjusted.	Move stick to deflect surface to full travel. Check for clearance between stops and bellcrank.	Adjust actuator piston end properly.
Actuator not adjusted to divide available travel equally between up and down positions.	Check total amount of actuator travel by disconnecting actuating rod and manually positioning control valve on actuator to bottom actuator full up and full down.	Adjust actuator piston end properly.
CONTROL STICK WILL NOT MOVE:		
Rig pin installed.	Check all rig pin points.	Remove rig pin.
Mechanical interference.	Check complete system for interference.	Rework as necessary.

Table 4-5.—Flight symptom analysis

SYMPTOM	REMEDY
Aileron(s) deflect during positive G loads.	Check for air in hydraulic systems. Check lateral control linkage for slop and misrigging.
Control stick binds or stick movement is stiff.	Check spring cartridge and screw jack actuators for binding, replace if required. Check flex shaft for insufficient slack or kinks. Check jam nut on rod end for secureness against screw jack shoulder and proper lockwire connection. Check aileron power control cylinder pivot bolt for over-torque and/or corrosion.
Aileron(s) flutter at high airspeeds.	Damper rod end broken.
Aileron(s) raise too far.	Damper rod end broken.
No lateral trim.	Refer to Paragraph 4-45.
No left trim.	Refer to Paragraph 4-49.
No right trim.	Refer to Paragraph 4-53.
Improper flap operation and ailerons do not droop.	On F-4B 152995z AND UP, RF-4B 153101z AND UP, AND F-4J 153071z THRU 154785af; ALSO F-4B 148363f THRU 152994y AND RF-4B 151975t THRU 153100y AFTER AFC 218, bleed flap and droop aileron hydraulic system.
	On F-4J 154786ag AND UP, refer to Paragraph 4-61.
Improper flap operation and ailerons do not move to neutral (streamlined).	On F-4B 152995z AND UP, RF-4B 153101z AND UP, AND F-4J 153101z THRU 154785af; ALSO F-4B 148363f THRU 152994y AND RF-4B 151975t THRU 153100y AFTER AFC 218, isolate malfunction in flap and droop aileron control system. Refer to Section VIII, Flap Control System.
	On F-4J 154786ag AND UP, refer to Paragraph 4-64.
Trim is slow.	Wrong grease on telescope. Flex shaft pulled too tight.
Trim does not run full left or full right.	Screw jack and/or rotary actuator bottoming out. Rerig feel trim system (Synchronizing Actuators to Neutral).
Stick is too free and does not center when trimmed to neutral (ailerons not neutral).	Spring cartridge and screw jack actuator rod end improperly adjusted.
Trim position indicator does not agree with trim position.	Readjust wing position transmitter.
Incorrect aileron position with control stick trimmed to neutral.	Check control and feel trim system rigging. On F-4B 152995z AND UP, RF-4B 153101z AND UP, AND F-4J; ALSO F-4B 148363f THRU 152994y AND RF-4B 151975t THRU 153100y AFTER AFC 218, check droop aileron mechanism rigging.

Table 4-6.–Trouble analysis procedure

4-45. NO LEFT OR RIGHT TRIM. See Figure 4-3.

4-46. Tools and Equipment.

External Electrical Power Source	(1, Figure 2-2)
Multimeter	(4, Figure 2-2)

4-47. Manpower Requirements.

a. Two men required.

4-48. Procedure.

	NO	YES
a. Apply external electrical power to the aircraft. Refer to NAVAIR 01-245FDB-2-1.1. General Airframe Information.	-	-
b. Check for 28 vdc at pin U on connector 52-P204. Does 28 vdc exist at pin U?	c	d
c. Isolate malfunction in main power supply system. Refer to NAVAIR 01-245FDB-2-5.1, Electrical Power Supply System. Repair or replace faulty component as required.	-	-
d. Check continuity between pin U and pin N on connector 52-J204. Does continuity exist?	e	f
e. Replace circuit breaker 22-CB204.	-	-
f. Check for 115 vac at pin L on connector 52-P204. Does 115 vac exist at pin L?	c	g
g. Check continuity between pin L and pin W on connector 52-J204. Does continuity exist?	h	i
h. Replace circuit breaker 22-CB203.	-	-
i. Place trim switch to left and check for 115 vac at pin A on connector 22-P506. Does 115 vac exist at pin A?	j	m
j. Place trim switch to left and check for 28 vdc at: pin m on connector 52-P357A on F-4 pin s on connector 52-P357A on RF-4 Does 28 vdc exist?	l	k
k. Replace No. 2 Misc. Relay Panel on F-4B. Replace No. 1 Misc. Relay Panel on F-4J AND RF-4B.	-	-
l. Replace trim switch 22-S241.	-	-
m. Check for proper connection between pin C on connector 22-P506 to ground. Is pin C properly grounded?	n	o
n. Replace faulty connection at pin C on connector 22-P506 to ground.	-	-
o. Cycle control stick. Does it move freely?	p	q
p. Check for binding condition in lateral control linkage. Repair or replace faulty component as required.	-	-
q. Replace the feel trim rotary actuator 22-B506.	-	-

4-49. NO LEFT TRIM. See Figure 4-3.

4-50. Tools and Equipment.

External Electrical Power Source	(1, Figure 2-2)
Multimeter	(4, Figure 2-2)

4-51. Manpower Requirements.

a. Two men required.

4-52. Procedure.

	NO	YES
a. Apply external electrical power to the aircraft. Refer to NAVAIR 01-245FDB-2-1.1, General Airframe Information	-	-
b. Place trim switch left and check for 115 vac at pin A on connector 22-P506. Does 115 vac exist at pin A?	c	f
c. Place trim switch to left and check for 28 vdc at: pin m on connector 52-P357A on F-4 pin S on connector 52-P357A on RF-4 Does 28 vdc exist?	d	e
d. Replace trim switch 22-S241.	-	-
e. Replace No. 2 Misc. Relay Panel on F-4B. Replace No. 1 Misc. Relay Panel on F-4J AND RF-4B.	-	-
f. Does feel trim rotary actuator run when trim switch is placed full left?	g	h
g. Replace feel trim rotary actuator 22-B506.	-	-
h. Check flex shaft between feel trim rotary actuator and left spring cartridge and screw jack actuator. Is flex shaft broken?	j	i
i. Replace flex shaft between feel trim rotary actuator and left spring cartridge and screw jack actuator.	-	-

RIGGING

Rigging a control system generally involves a detailed step-by-step procedure which will vary somewhat with different aircraft; however, the entire operation can be broken down into the following main steps:

1. Neuturalizing the system.
2. Establishing correct cable tension.
3. Checking and limiting the travel of the control surface.

Neutralizing the System

Neutralizing a control system is accomplished by securing the cockpit control in the neutral position, then neutralizing each bellcrank in the system, beginning with the stick bellcrank and working out to the control surface.

Aircraft manufacturers provide various means of accomplishing this step. Some type of control lock (harness or sling) is generally provided for securing the cockpit control in the neutral position, and either rig pin holes or index marks are provided at each bellcrank.

Each bellcrank is neutralized by adjusting the applicable push rod or cable until the rig pin holes or index marks are aligned. Push rods have adjustable end fittings, and each cable is equipped with a turnbuckle for making adjustments.

After all rig pins are installed (or index marks are aligned), the control surface should be in the neutral position. Normally, a rigging fixture is used to find the neutral position. If the control surface is not in alignment, reference should be made to the applicable Maintenance Instructions Manual for the step-by-step procedure for making the adjustment.

Establishing Cable Tension

Correct cable tension is necessary in order to obtain proper response of the control surface to the cockpit control. Low cable tension may cause sluggishness, free play, flutter, or insufficient travel of the control surface. Excessively high cable tension will cause increased system friction and may result in damage to pulley or bellcranks, or to the cable itself.

Cable tension is checked with a tensiometer and adjustments made at the turnbuckles. Detailed instructions in the use of the tensiometer are presented in AMS 3 & 2, NavTra 10308-C.

Checking and Limiting Control Surface Travel

Control surface travel is checked by measuring the extent of movement in each direction from neutral. Travel is generally specified in degrees. Rigging fixtures similar to those shown in figure 4-23 are generally provided for checking travel. If none are provided, suitable checking devices can be made up in the shop.

Control surface travel is limited by adjustable stops. One set is generally located near the cockpit control and another set near the control surface. These stops should always be set in accordance with the applicable aircraft Maintenance Instructions Manual.

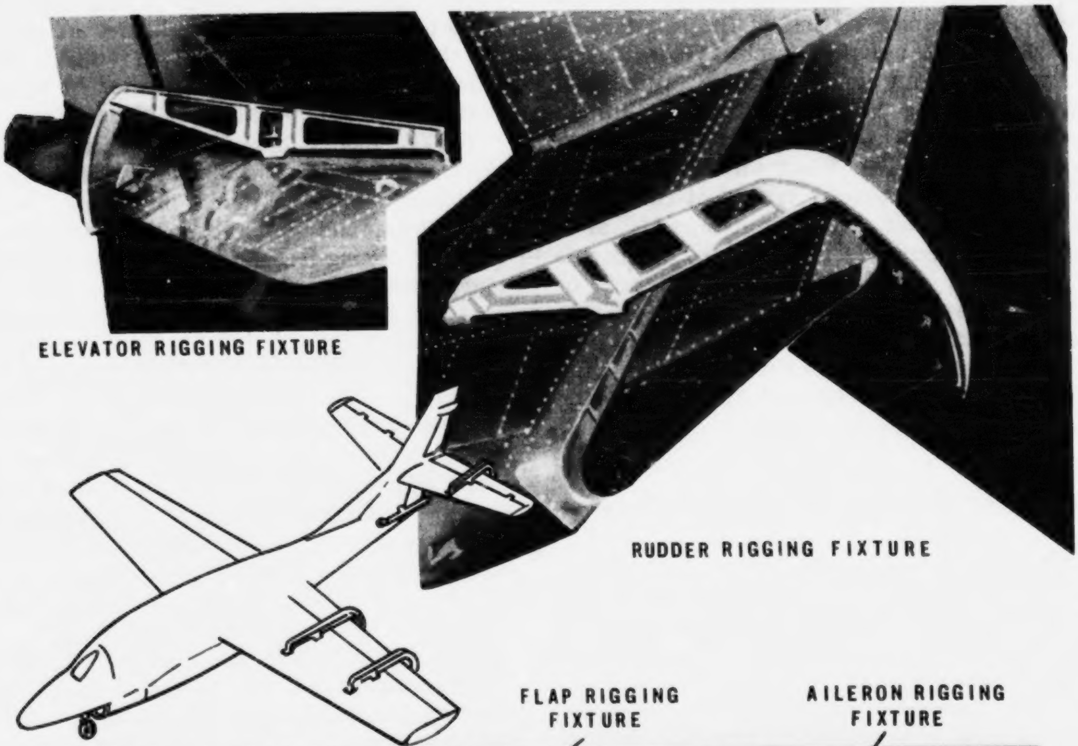
In systems utilizing power boost, control surface travel may be limited by making adjustments to the actuator. This is accomplished by adjusting the actuator piston rod end until the control surface travel falls within the limits specified in the applicable aircraft Maintenance Instructions Manual.

ROTOR BLADE TRACKING

Blade tracking must be performed whenever a helicopter has been rerigged, or the blades, the main gearbox, or the main rotor head assembly has been replaced. Unless the blades are in proper track, vibrations will occur in the helicopter with every revolution of the main rotor. At high rpm settings these vibrations could cause serious structural damage.

NOTE: The following information is provided to give the reader a general knowledge of the procedures used in tracking the main rotor blades of the SH-3A helicopter.

Tracking the blades is necessary to insure that all of the blades rotate in the same horizontal


ELEVATOR RIGGING FIXTURE
RUDDER RIGGING FIXTURE
FLAP RIGGING FIXTURE
AILERON RIGGING FIXTURE

AM.467

Figure 4-23.—Typical rigging fixtures.

plane (track). This is accomplished on the SH-3A by pretrack rigging of the rotary wing head, and by the use of pretracked blades.

Pretrack rigging of the rotary wing head involves adjusting the pitch control rods until an exact sleeve angle, within 1 minute, is attained on all sleeve spindles. When this exact angle is established, a micrometer type decal is affixed on the adjustable pitch control rods as a permanent reference. A pretrack number is stenciled on each blade at manufacture or overhaul, based on the effective angle of the blade. Accordingly, any pretracked blade can be installed on the helicopter simply by setting the adjustable pitch control rod to the pretrack number stenciled on the blade.

TRACKING PROCEDURE

When tracking blades after installation, proceed as follows: With the rotary wing blades installed, set each adjustable pitch control rod to the pretrack number stenciled on the underside of the blade. If the pretrack number is MINUS, and the adjustable pitch control rod decal indicates that it is set at 0, loosen the locknut and shorten the rod by rotating the tang clockwise until it aligns with (closest notch to) the appropriate blade pretrack number on the lower scale of lower decal. Engage the tang by tightening the locknut. If the pretrack number of the blade is PLUS, and the adjustable pitch control rod decal indicates that it is set at 0, loosen the locknut and lengthen the rod by rotating the tang counterclockwise until it aligns with (closest notch to) the appropriate blade pretrack number on the upper scale of the lower decal. After adjusting the remainder of the pitch control rods, tighten the locknuts to 200 to 250 inch-pounds torque and safetywire the locknuts to the tang.

Next, a ground operational check must be performed. With the rotary wing head engaged, operate the engines at 100 percent and check for possible vibrations in the rotary wing head. If the blades are not in track, and the adjustable pitch control rods were properly set to the pretrack numbers on the blades, and alternate method of tracking the blades is available. In this case, an electronic blade tracker is used to check the blades under actual operating conditions to insure that all blades are rotating in the same horizontal plane (track). Pitch adjustment of each blade can then be made, if necessary to compensate for blade differences.

NOTE: Blades must not be adjusted for the electronic method of blade tracking unless problems are encountered in normal tracking procedures, and it has been decided that the pretrack rigging feature of the rotary wing head and blades will not be used.

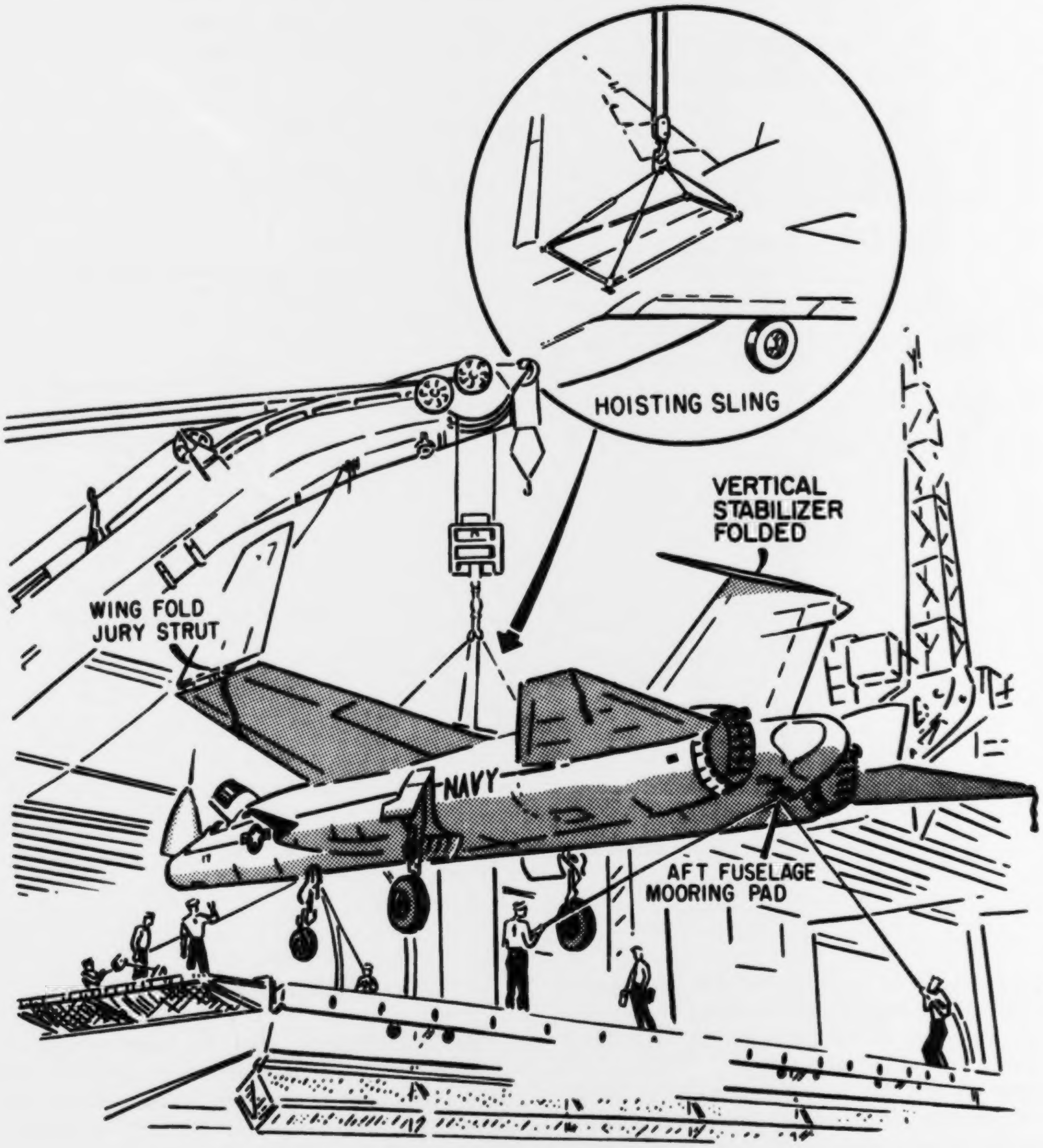
AIRCRAFT HOISTING

When facilities are available, particularly aboard carriers, it might become necessary to hoist the aircraft to perform limited maintenance, instead of jacking it. The pitching and rolling of the ship makes jacking and hoisting of aircraft very hazardous. When the carrier is tied up to a pier, the loading and unloading of aircraft is also accomplished by hoisting.

Each aircraft has points for attaching hoisting slings, usually near the center of gravity. The hoisting points and procedures for hoisting are outlined in the applicable Maintenance Instructions Manual. The hoisting slings are especially designed for each type aircraft and are furnished as part of its ground-handling equipment. Figure 4-24 shows an aircraft rigged for hoisting.

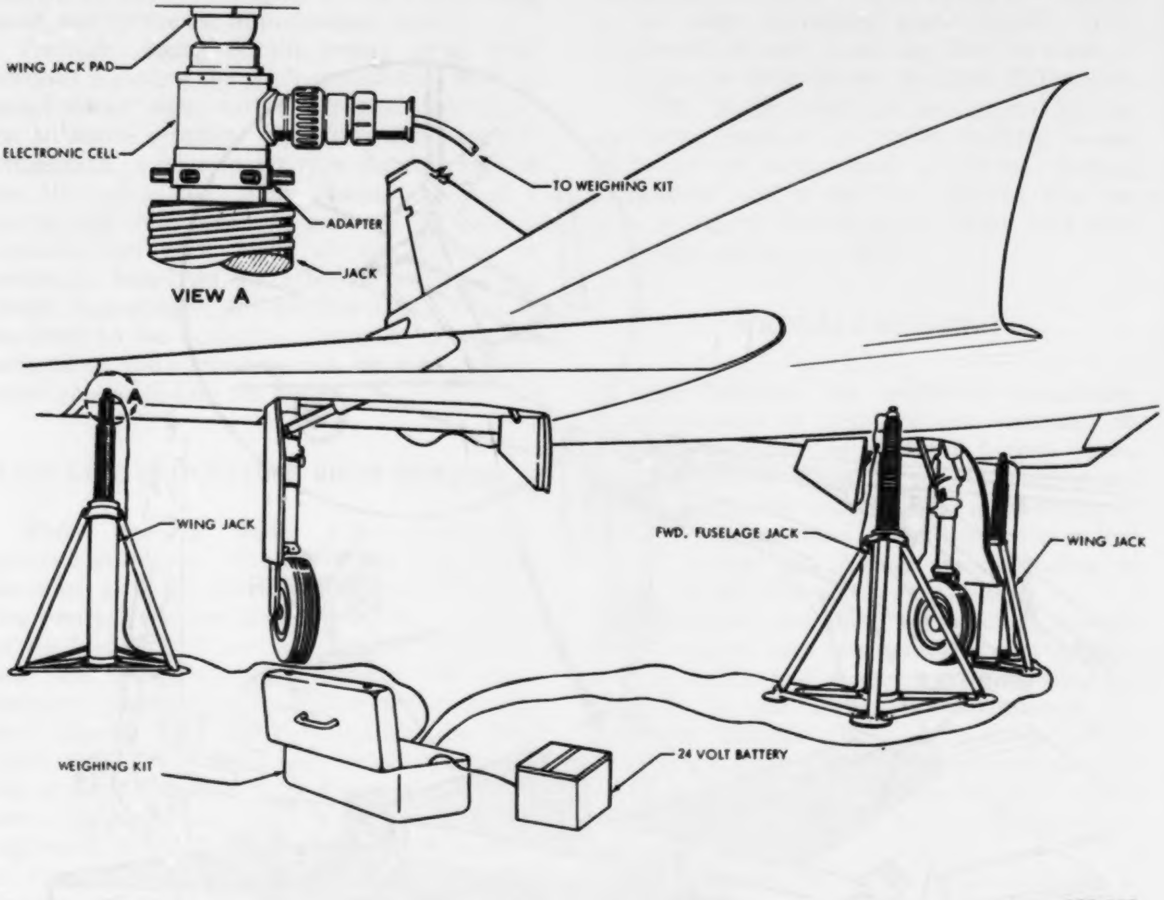
Hoisting an aircraft should be accomplished in a slow steady manner. The following general precautions should be observed at all times during hoisting and loading operations:

1. Insure that the hoisting device is of suitable capacity to lift the aircraft safely.
2. Insure that the hoisting sling and any adapters are in good conditions and properly installed. NEVER use a damaged sling or adapter to hoist an aircraft.
3. Insure that all ground safety devices, including the landing gear ground safety locks are installed.
4. Insure that fore and aft steady lines of sufficient length are installed and manned.
5. Inspect the area for clearance and safety harzards.
6. Caution handling personnel not to stand directly beneath aircraft while it is suspended.


HOISTING SLING
VERTICAL STABILIZER FOLDED
WING FOLD JURY STRUT
NAVY
AFT FUSELAGE MOORING PAD

AM.468

Figure 4-24.—Hoisting an aircraft.


WING JACK PAD
ELECTRONIC CELL
TO WEIGHING KIT
ADAPTER
JACK
VIEW A
A
WING JACK
FWD. FUSELAGE JACK
WING JACK
WEIGHING KIT
24 VOLT BATTERY

AM.469

Figure 4-25.—Aircraft weighing.

The precautions listed above are general and apply to any aircraft. Before hoisting an aircraft, the Maintenance Instructions Manual should be checked for specific instructions.

Large aircraft subassemblies, such as wings and tail sections, are also provided with hoisting points for removal and installation. These points are also generally located near the center of gravity of the subassembly. The same procedure and care must be exercised when hoisting the subassemblies as when hoisting the complete aircraft.

AIRCRAFT WEIGHING

The manufacturer provides basic weight and balance data with each aircraft at delivery. This data is recorded in the Weight and Balance Data Handbook, NavAir 01-1B-40. All subsequent changes which affect the basic weight and balance must be compiled and recorded in the Weight and Balance Data Handbook according to instructions contained in this handbook. This means that the aircraft must be weighed when major repairs or modifications are made, when unsatisfactory flight conditions are encountered (nose or tail heaviness), and as required by pertinent directives.

The aircraft should be weighed in its basic weight condition; that is, with fixed equipment which is acutally present in the aircraft, less fuel and other expendable load items.

Weighing is usually accomplished with an electronic weighing kit similar to the one illustrated in figure 4-25.

The following is a typical aircraft weighing procedure:

1. Prepare the aircraft in accordance with the Weight and Balance Data Handbook.
2. Place the aircraft in a hangar with the doors closed and all blowers in the immediate area turned off.
3. Place the proper jacks under the jack pads.
4. Place the electronic weighing cells on the jacks (using adapters if needed). (See fig. 4-25.)

NOTE: Zero the electronic cells in accordance with the manufacturer's recommendations.

5. Raise the jacks evenly until the aircraft is level, with the wheels off the deck.

NOTE: Jack the aircraft in accordance with the instructions in the applicable Maintenance Instructions Manual.

6. Level the aircraft, using the method recommended in the aircraft Structural Repair Manual or Maintenance Instructions Manual.

7. Take the weight readings with the aircraft in this condition.

NOTE: When using a battery powered weighing kit, the battery must be fully charged or the readings will be erratic.

Figure 4-25 shows an aircraft prepared for weighing.

CHAPTER 5

HEAT TREATMENT AND TESTING OF METALS

HEAT TREATMENT

Heat treatment is a series of operations involving the heating and cooling of metals in the solid state. Its purpose is to change a mechanical property or combination of mechanical properties so that the metal will be more useful, serviceable, and safe for a definite purpose. By heat treating, a metal can be made harder, stronger, and more resistant to impact. Heat treating can also make a metal softer and more ductile. No one heat-treating operation can produce all of these characteristics. In fact, some properties are often improved at the expense of others. In being hardened, for example, a metal may become brittle.

The various heat-treating processes are similar in that they all involve the heating and cooling of metals. They differ, however, in the temperatures to which the metal is heated, the rate at which it is cooled, and of course, in the final result.

PRINCIPLES OF HEAT TREATMENT

Internal Structure of Metals

The results that may be obtained by heat treatment depend to a great extent on the structure of the metal and on the manner in which the structure changes when the metal is heated and cooled. A pure metal cannot be hardened by heat treatment because there is little change in its structure when heated. On the other hand, most alloys respond to heat treatment since their structures change with heating and cooling.

An alloy may be in the form of a solid solution, mechanical mixture, or a combination of a solid solution and a mechanical mixture. When an alloy is in the form of a solid solution, the elements and compounds which form the alloy are absorbed, one into the other, in much the same way that salt is dissolved in a glass of water, and the constituents cannot be identified even under a microscope.

When two or more elements or compounds are mixed but can be identified by microscopic examination, a mechanical mixture is formed. A mechanical mixture might be compared to the mixture of sand and gravel in concrete. The sand and gravel are both visible. Just as the sand and gravel are held together and kept in place by the mixture of cement, the other constituents of an alloy are embedded in the mixture formed by the base metal.

An alloy which is in the form of a mechanical mixture at ordinary temperatures may change to a solid solution when heated. When cooled back to normal temperature, the alloy may return to its original structure. On the other hand, it may remain a solid solution or form a combination of a solid solution and mechanical mixture. An alloy which consists of a combination of solid solution and mechanical mixture at normal temperatures may change to a solid solution when heated. When cooled, the alloy may remain a solid solution, return to its original structure, or form a complex solution.

Behavior of Steel During Heating and Cooling

Changing the internal structure of a ferrous metal is accomplished by heating to a temperature above its upper critical point, holding it at that temperature for a time sufficient to permit certain internal changes to occur, and then cooling to atmospheric temperature under predetermined, controlled conditions.

At ordinary temperatures, the carbon in steel exists in the form of particles of iron carbide scattered throughout the iron mixture known as "ferrite." The number, size, and distribution of these particles determine the hardness of the steel. At elevated temperatures, the carbon is dissolved in the mixture in the form of a solid solution called "austenite," and the carbide particles appear only after the steel has been cooled. If the cooling is slow, the carbide particles are relatively coarse and few. In this condition the steel is soft. If the cooling is rapid, as by quenching in oil or water, the carbon precipitates as a cloud of very fine carbide particles and the steel is hard. The fact that the carbide particles can be dissolved in austenite is the basis of the heat treatment of steel. The temperatures at which this transformation takes place are called the critical points and vary with the composition of the steel. The element normally having the greatest influence is carbon.

HEAT TREATMENT OF FERROUS METALS

The first important consideration in the heat treatment of a steel part is to know its chemical composition. This, in turn, determines its upper critical point. When the upper critical point is known, the next consideration is the rate of heating and cooling to be used. The carrying out of these operations involves the use of uniform-heating furnaces, proper temperature controls, and suitable quenching mediums.

GENERAL HEAT-TREATING PRACTICES

Heating

The aim in heating is to transform pearlite to austenite as the steel is heated through the critical range. Since this transition takes time, a relatively slow rate of heating must be employed. Ordinarily, the cold steel is inserted when the temperature in the furnace is 300° to 500° F below the hardening temperature. In this way, too rapid heating through the critical range is prevented.

Soaking

The temperature of the furnace must be held constant during the soaking period, since it is during this period that rearrangement of the internal structure of the steel takes place. Soaking temperatures for various types of steel are specified in ranges varying as much as 100° F. (See table 5-1.) Small parts are soaked in the lower part of the specified range and heavy parts in the upper part of the specified range. The length of the soaking period depends upon the type of steel and the size of the part. Naturally, heavier parts require longer soaking to insure equal heating throughout. As a general rule, a soaking period of 1 hour is sufficient for the average heat-treating operation.

Cooling

The rate of cooling through the critical range determines the form that the steel will retain. Various rates of cooling are employed to produce the desired results. Still air is a slow cooling medium, but is much faster than furnace cooling. Liquids are the fastest cooling media and therefore used in hardening steels.

There are three commonly used quenching liquids–brine, water, and oil. Brine is the most severe medium, water is next, and oil is the least severe. Generally, an oil quench is used for alloy steels, and brine or water for carbon steels.

The tendency of steel to warp and crack during the quenching process is difficult to overcome because certain parts of the article cool more rapidly than others. The following recommendations will greatly reduce the warping tendency:

1. An article should never be thrown into the quenching bath. By permitting it to lie on the bottom of the bath it is apt to cool faster on the top side than on the bottom side, thus causing it to warp or crack.

2. The article should be agitated slightly to destroy the coating or vapor which might prevent it from cooling rapidly. This

allows the bath to convey its heat to the atmosphere.

3. Irregular shaped articles should be immersed in such a manner that the heavy end enters the bath first.

HARDENING

Pure iron, wrought iron, and extremely low-carbon steels cannot be appreciably hardened by heat treatment, since they contain no hardening element. Cast iron can be hardened, but its heat treatment is limited. When cast iron is cooled rapidly, it forms white iron, which is hard and brittle. When cooled slowly, it forms gray iron, which is soft but brittle under impact.

In plain-carbon steel, the maximum hardness depends almost entirely on the carbon content of the steel. As the carbon content increases, the ability of the steel to be hardened increases. However, this increase in hardenability with an increase in carbon content continues only to a certain point. In practice, that point is 0.85 percent carbon content. When the carbon content is increased beyond 0.85 percent, there is no increase in hardenability, but there is an increase in wear resistance. This increase in wear resistance is due to the formation of hard cementite.

To harden steel, it must be heated to a temperature just above the upper critical point, soaked at that temperature long enough to insure an austenitic condition throughout the steel, and then cooled rapidly.

When hardening carbon steel, remember that the steel must be cooled to below 1,000° F in less than 1 second. Should the temperature drop to 1,000° exceed 1 second, the austenite begins to transform into fine pearlite. This pearlite varies in hardness, but is much harder than the pearlite formed by annealing and much softer than the martensite desired. After the 1,000° temperature is reached, the rapid cooling must continue if the final structure is to be all martensite.

When alloys are added to steel, the time limit for the temperature drop to 1,000° F increases above the 1-second limit for carbon steels. Therefore, a slower quenching medium will produce hardness in alloy steels.

Hardening increases the hardness and strength of the steel, but makes it less ductile.

Because of the high internal stresses in the "as quenched" condition, steel must be tempered just before it becomes cold. The part should be removed from the quenching bath at a temperature of approximately 200° F, since the temperature range from 200° down to room temperature is the cracking range.

Hardening temperatures and quenching mediums for carbon and low-alloy steels are listed in table 5-1.

TEMPERING

Tempering produces definite physical properties within the steel. Tempering always follows, never precedes, the hardening operation. After the hardening treatment, steel is often harder than necessary and is too brittle for most practical uses. In addition, severe internal stresses are set up during the rapid cooling from the hardening temperature. To relieve the internal stresses and reduce brittleness, steel is tempered after being hardened.

Tempering is always conducted at temperatures below the critical point of the steel. In this respect, tempering differs from annealing, normalizing, and hardening, in which the temperatures are above the upper critical point. When hardened steel is reheated, tempering begins at 212° F and continues as the temperature increases toward the low critical point. By selecting a definite tempering temperature, the resulting hardness and strength can be predetermined. Approximate temperatures for various tensile strengths are listed in table 5-1. The minimum time at the tempering temperature should be 1 hour. If the part is over 1 inch in thickness, the time should be increased by 1 hour for each additional inch of thickness. Tempered steels, as used in aircraft work, have from 125,000 to 200,000 psi ultimate tensile strength.

Generally, the rate of cooling from the tempering temperature has no effect on the resulting structure; therefore, the steel is usually cooled in still air after being removed from the furnace.

ANNEALING

Annealing of steel produces a fine grained, soft, ductile metal without internal stresses or strains. In the annealed state, steel has its lowest strength.

Table 5-1.–Heat-treatment procedure (carbon and low alloy steels)

SAE AISI or producer's designation	Austenitizing temperatures and cooling requirements (°F)						Approximate tempering temperature °F, for tensile strength, 1,000 psi.						
		Annealing		Transformation hardening cycle		Recommended subcritical anneal	100	120 to 140	140 to 160	160 to 180	180 to 200	200 to 220	Min. tempering temp.
	Normalizing, air cool	Heating	Furnace cool to or below approx. temp. shown	Heat to	Quench in								
1025	1,600 to 1,700	1,575 to 1,650	900	1,575 to 1,650	Water	1,250							700
1035	1,600 to 1,700	1,575 to 1,650	900	1,525 to 1,600	Water	1,250	900						700
1045	1,600 to 1,700	1,550 to 1,600	900	1,500 to 1,575	Oil or Water	1,250	1,100						700
1095	1,500 to 1,600	1,450 to 1,525	900	1,450 to 1,525	Oil or Water	1,250			1,050	850	750		
3140	1,600 to 1,700	1,450 to 1,525	900	1,475 to 1,525	Oil	1,250	1,250	1,100	1,000	825	700		700
4037	1,600 to 1,700	1,525 to 1,575	900	1,525 to 1,575	Oil	1,200	1,200	1,100	925				700
4130	1,600 to 1,700	1,550 to 1,600	900	1,500 to 1,600	Oil	1,250	1,250	1,050	925	850	725		700
4135	1,600 to 1,700	1,525 to 1,575	900	1,550 to 1,625	Oil	1,250		1,125	1,025	900	800		700
4140	1,600 to 1,700	1,525 to 1,575	900	1,525 to 1,600	Oil	1,250	1,300	1,175	1,075	950	850	725	700
4150	1,525 to 1,650	1,500 to 1,550	900	1,500 to 1,575	Oil	1,250		1,200	1,100	975	800		700

Table 5-1.—Heat-treatment procedure (carbon and low alloy steels)—continued

SAE AISI or producer's designation	Austenitizing temperatures and cooling requirements (°F)						Approximate tempering temperature °F for tensile strength, 1,000 psi.						
	Normalizing, air cool	Annealing		Transformation hardening cycle		Recommended subcritical anneal	100	120 to 140	140 to 160	160 to 180	180 to 200	200 to 220	Min. tempering temp.
		Heating	Furnace cool to or below approx. temp. shown	Heat to	Quench in								
4330V	1,600 to 1,700	1,525 to 1,600	800	1,550 to 1,650	Oil or Air						1,000	800	700
4335V	1,600 to 1,700	1,525 to 1,600	800	1,550 to 1,650	Oil or Air						1,000	800	700
4340	1,600 to 1,700	1,525 to 1,575	700	1,475 to 1,550	Oil	1,250				1,050	925	850	725
4640	1,600 to 1,700	1,525 to 1,575	750	1,500 to 1,550	Oil	1,200	1,200	1,100	1,000	900	750		700
8735	1,600 to 1,700	1,525 to 1,575	900	1,525 to 1,600	Oil	1,250		1,125	1,025	800	785		700
8740	1,600 to 1,700	1,500 to 1,575	900	1,525 to 1,600	Oil	1,250		1,175	1,075	950	850	725	700
52100	1,600 to 1,700	1,400 to 1,450	700	1,500 to 1,575	Oil	1,250							700
6150	1,600 to 1,700	1,525 to 1,575	900	1,550 to 1,625	Oil	1,250							700
8630	1,600 to 1,700	1,525 to 1,575	900	1,550 to 1,625	Oil	1,250	1,250	1,050	925	850	725		700
Si-Cr (For Springs)				1,700 to 1,725	Oil		Temper at 800° F and air cool for Rockwell hardness of C-50						

Annealing of steel is accomplished by heating the metal to just above the upper critical point, soaking at that temperature, and cooling very slowly in the furnace itself. (See table 5-1 for recommended temperatures.) Soaking time is approximately 1 hour per inch thickness of the material. Slow cooling is obtained by shutting off the heat and allowing the furnace and metal to cool together to 900° F or lower, then removed from the furnace and cooled in still air. Another method is to bury the heated steel in ashes, sand, or other substances that do not conduct heat readily.

NORMALIZING

Normalizing of steel removes the internal stresses set up by heat-treating, welding, casting, forming, or machining. Stress, if not controlled, will lead to failure. Because of the better physical properties, aircraft steels are often used in the normalized state, but seldom, if ever, in the annealed state.

One of the most important uses of normalizing in aircraft work is in welded parts. Welding causes strains to be set up in the adjacent material. In addition, the weld itself is a cast structure as opposed to the wrought structure of the rest of the material. These two types of structure have different grain sizes, and to refine the grain as well as to relieve the internal stresses, all welded parts should be normalized after fabrication.

Normalizing is accomplished by heating the steel above the upper critical point, holding it at that temperature until it is uniformly heated, and cooling in still air. The more rapid quenching obtained by air cooling, as compared to furnace cooling, results in a harder and stronger material than that obtained by annealing. Recommended normalizing temperatures for the various types of aircraft steels are listed in table 5-1.

CASEHARDENING

The object in casehardening is to produce a hard case over a tough core. Casehardening is ideal for parts which require a wear-resistant surface and, at the same time, must be tough enough internally to withstand the applied loads. The steels best suited to casehardening are the low-carbon and low-alloy steels. If high-carbon steel is casehardened, the hardness penetrates the core and causes brittleness.

In casehardening, the surface of the metal is changed chemically by introducing a high carbide or nitride content. The core is unaffected chemically. When heat treated, the surface responds to hardening while the core toughens. The common forms of casehardening used in aircraft work are carburizing and nitriding.

Carburizing

Carburizing is a casehardening process in which carbon is added to the surface of low-carbon steel. Thus, a carburized steel has a high-carbon surface and a low-carbon interior. Therefore, the case is hardened while the core remains soft and tough.

A common method of carburizing is that called "pack carburizing." When carburizing is to be done by this method, the steel parts are packed in a container with charcoal or some other material rich in carbon. The container is then sealed with fire clay, placed in a furnace, heated to approximately 1,700° F, and soaked at that temperature for several hours. As the temperature increases, carbon monoxide gas forms inside the container and, being unable to escape, combines with the gamma iron in the surface of the steel. The depth of which the carbon penetrates depends on the length of the soaking period. For example, when carbon steel is soaked for 8 hours, the carbon penetrates to a depth of about 0.062 inch.

In another method of carburizing, called "gas carburizing," a material rich in carbon is introduced into the furnace atmosphere. The carburizing atmosphere is produced by the use of various gases or by the burning of the wood, or other materials. When the steel parts are heated in this atmosphere, carbon monoxide combines with the gamma iron to produce practically the same results as those described under the pack-carburizing process.

A third method of carburizing is that of "liquid carburizing." In this method the steel is placed in a molten salt bath that contains the chemicals required to produce a case comparable with one resulting from pack or gas carburizing.

Alloy steels with low-carbon content as well as low-carbon steels may be carburized by either of the three processes. However, some alloys, such as nickel, tend to retard the absorption of carbon. As a result, the time required to produce a given thickness of case varies with the analysis of the metal.

The following steels are frequently used for carburized parts:

SAE Number	Core Strength (psi)
1020	60,000
2320	80,000
2515	120,000
3115	85,000
3312	100,000
4615	80,000

Nitriding

Nitriding is unlike other casehardening processes in that, before nitriding, the part is heat-treated to produce definite physical properties. Thus, parts are hardened and tempered before being nitrided. Most steels can be nitrided, but special alloys are required for best results. These special alloys contain aluminum as one of the alloying elements and are called "nitralloys."

In nitriding, the part is placed in a special nitriding furnace and heated to a temperature of approximately 1,000° F. With the part at this temperature, ammonia gas is circulated within the specially constructed furnace chamber. The high temperature cracks the ammonia gas into nitrogen and hydrogen. The ammonia which does not break down is trapped in a water trap below the regions of the other two gases. The nitrogen reacts with the iron to form iron nitride. The iron nitride is dispersed in minute particles at the surface and works inward, the depth of penetration depending on the length of the treatment. In nitriding, soaking periods as long as 72 hours are frequently required to produce the desired thickness of case.

Nitriding can be accomplished with a minimum of distortion, because of the low temperature at which parts are casehardened and because no quenching is required for exposure to the ammonia gas.

Flamehardening

The flamehardening process employs the heat of an oxyacetylene flame to produce a relatively shallow heated zone in a ferrous material such that subsequent quenching with suitable media, generally water, compressed air, or a soluble oil, will increase its surface hardness. The main difference between furnace hardening and flamehardening is that in the former process the entire object must be brought to hardening temperature, whereas in the latter, only a thin surface layer, about 1/16 to 1/8 inch in thickness, or a localized area is so treated.

Flamehardening employs the flame merely as a heating medium and involves no change in the chemical composition of the material such as the introduction of carbon or nitrogen into the surface layers of the material, as in casehardening. Because of the rapid rate of heating and the sharp temperature gradient between the surface and the interior of the object, a substantial self-quenching effect is obtained, which in some cases is sufficient to produce the desired surface hardness by air cooling.

HEAT TREATMENT OF ALUMINUM ALLOYS

(Material in this section is supplied by Reynolds Metals Company, Louisville, Kentucky.)

The hardening of an aluminum alloy by heat treatment consists of the following four distinct steps:

1. Heating to a predetermined temperature.
2. Soaking at temperature for a specified length of time.
3. Rapidly quenching to a relatively low temperature.
4. Aging or precipitation hardening either spontaneously at room temperature, or as a result of a low-temperature thermal treatment.

The first three steps above are known as solution heat treatment, although it has become common practice to use the shorter term, heat treatment. Room-temperature hardening is known as natural aging, while hardening done at moderate temperatures is called artificial aging, or precipitation heat treatment.

The alloys that require precipitation heat treatment (artificial aging) to develop their full strength also age to a limited extent at room temperature, the rate and amount of strengthening depending upon the alloy. Some reach their maximum natural or room-temperature aging strength in a few days, and are designated as -T4 or -T3 temper. Others continue to age appreciably over a long period of time. Because of this natural aging, the -W designation is specified only when the period of aging is indicated; for example, 7075-W (1/2 hour). Thus, there is considerable difference in the mechanical and physical properties of freshly quenched (-W) material and material that is in the -T3 or -T4 temper. The fact that material in the -T3 or -T4 temper is already in a partially aged condition should always be kept in mind.

HEAT-TREATING PRACTICES

Temperature

The temperatures used for solution heat-treating vary with different alloys, ranging from 825° to 980° F. As a rule, they must be controlled within a very narrow range (plus or minus 10°) to obtain specified properties.

If the temperature is too low, maximum strength will not be obtained. When excessive temperatures are used, there is danger of melting the low-melting constituents of some alloys. Even if melting does not occur, the use of higher-than-recommended temperatures promotes discoloration and increases quenching strains.

Time at Temperature

The time at temperature, referred to as soaking time, is measured from the time the coldest metal reaches the minimum limit of the desired temperature range. The soaking time varies, depending upon the alloy and thickness, from 10 minutes for thin sheet to approximately 12 hours for heavy forgings. For the heavy sections, the nominal soaking time is approximately 1 hour for each inch of cross-sectional thickness.

The soaking time is so chosen as to put substantially all of the soluble elements into solid solution. The effect of an abbreviated soaking time is obvious. An excessive soaking period aggravates high-temperature oxidation. With clad material, prolonged heating results in excessive diffusion of copper and other soluble constituents into the protective cladding and may defeat the purpose of cladding.

Heating Rate

If cold work is present in the metal, the heating rate should be reasonably fast to prevent the formation of coarse grains. Generally, no grain size difficulty will be encountered unless a critical amount of cold work is present.

Quenching

After the soluble constituents are in solid solution, the material is quenched to prevent or retard immediate precipitation. Three distinct quenching methods are employed. The one to be used in any particular instance depends upon the commodity, the alloy, and the properties desired.

Cold Water Quenching

Parts produced from sheet, extrusions, tubing, small forgings, and similar type material are generally quenched in a cold water bath. The temperature of the water, before quenching, should not be in excess of 85° F. A sufficient quantity of water should be used to keep the temperature rise under 20° F. Such a drastic quench insures maximum resistance to corrosion. This is particularly important when working with such alloys as 2017 and 2024. This is the reason a drastic quench is preferred, even though a slower quench may produce the required mechanical properties.

Hot Water Quenching

Large forgings and heavy sections can be quenched in hot or boiling water. This type of quench minimizes distortion and alleviates cracking which may be produced by the unequal temperatures obtained during the quench. The use of such a quench is permitted with these classes of material because the temperature of the quench water does not critically affect the resistance to corrosion of the forging alloys. In addition, the resistance to corrosion of heavy sections is not as critical a factor as for thin sections.

Spray Quenching

High velocity water sprays are useful for parts formed from clad sheet and for large sections of almost all alloys. This type of quench also minimizes distortion and alleviates quench cracking. However, many specifications forbid the use of spray quenching for bare 2017 and 2024 sheet due to its effect on their resistance to corrosion.

Lag Between Soaking and Quenching

The time interval between the removal of the material from the furnace and quenching is critical for some alloys and should be held to a minimum. The recommended maximum time interval between removal from the heat and immersion is 10 seconds or less. The allowable time for heavy sections may be slightly greater.

Allowing the material to cool slightly before quenching promotes reprecipitation from the solid solution. The precipitation occurs along grain boundaries and in certain slip planes causing formability and, in the case of 2017 and 2024, adversely affects their resistance to intergranular corrosion. The strength and hardness of most alloys are not seriously affected unless the precipitation is severe.

Re-Solution Heat Treatment

The bare heat-treatable alloys can be solution heat-treated repeatedly without harmful effects. However, it is advisable to use either sodium or potassium fluoborate during the heating cycle as a protection against possible high-temperature oxidation.

The number of solution heat treatments allowed for clad sheet is limited due to increased diffusion of core and cladding with each reheating. Existing specifications allow one to three reheat treatments of clad sheet, depending upon cladding thickness.

Straightening After Solution Heat Treatment

Some warping occurs during solution heat treatment, producing kinks, buckles, waves, and twists. These imperfections are generally removed by straightening and flattening operations.

Where the straightening operations produce an appreciable increase in the tensile and yield strengths and a slight decrease in the percent elongation, the material is designated -T3 temper. When the above values are not materially affected, the material is designated -T4 temper.

DIFFICULTIES

The following difficulties may be encountered when solution heat-treating the aluminum alloys:

Low Tensile and Yield Strength

Causes are abbreviated soak or low temperature; slow transfer from furnace to quench tank; slow quench; overheating; and high-temperature oxidation.

Excessive Diffusion in Cladded Material

Causes include prolonged heating during solution heat treatment or during a previous high-temperature annealing operation and an excessive number of heat treatments.

Intergranular Corrosion

Intergranular corrosion is usually found only after long exposure to a salt water atmosphere. It drastically lowers the tensile strength and the percent elongation. Causes are slow transfer from furnace to quenching media, use of a mild quench; and uncontrolled or improper reheating to an elevated temperature after heat treatment.

Overheating

Overheating results in loss of ductility, and in severe cases, produces blisters and reduces, strength. It also promotes cracking during quenching.

NOTE: A substantial portion of the difficulties encountered in heat-treating aluminum alloys is due to improper or inadequate temperature control. This fact is well worth remembering. When any difficulties arise, it should be the first point checked.

HARDENING OF ALUMINUM ALLOYS

BASIC PRINCIPLES

As previously stated, the aluminum alloys are in a comparatively soft state immediately after quenching from a solution heat-treating temperature. To obtain their maximum strengths, they must be aged or precipitation-hardened.

During this hardening and strengthening operation, precipitation of the soluble constituents from the supersaturated solid solution takes place. As precipitation progresses, the strength of the material increases, often by a series of peaks, until a maximum is reached. Further aging (over-aging) causes the strength to steadily decline until a somewhat stable condition is obtained. The submicroscopic particles that are precipitated provide the keys or locks within the grain structure and between the grains to resist internal slippage and distortion when a load of any type is applied. In this manner, the strength and hardness of the alloy are increased.

Precipitation hardening produces a great increase in the strength and hardness of the material with corresponding decreases in the ductile properties. The process used to obtain the desired increase in strength is therefore known as aging or precipitation-hardening.

The strengthening of the heat-treatable alloys by aging is not due merely to the presence of a precipitate. Instead, it is due to both the uniform distribution of a finely dispersed submicroscopic precipitate and the distortion and other effects of its formation upon the crystal structure.

The aging practices used depend upon many properties other than strength. As a rule, the artificially aged alloys are slightly over-aged to increase their resistance to corrosion. This is especially true with the artificially aged high-copper-bearing alloys that are susceptible to intergranular corrosion when inadequately aged.

The heat-treatable aluminum alloys are subdivided into two classes–those that obtain their full strength at room temperature and those that require artificial aging.

The alloys that obtain their full strength after 4 or 5 days at room temperature are known as natural aging alloys. Precipitation from the supersaturated solid solution starts soon after quenching, with 90 percent of the maximum strength generally being obtained in 24 hours. Alloys 2017 and 2024 are natural aging alloys.

The alloys that require precipitation thermal treatment to develop their full strength are artificially aged alloys. However, these alloys also age a limited amount at room temperature, the rate and extent of the strengthening depending upon the alloys.

Many of the artificially aged alloys reach their maximum natural or room temperature aging strengths after a few days. These can be stocked for fabrication in the -T4 or -T3 temper. High zinc-bearing alloys such as 7075 continue to age appreciably over a long period of time, their mechanical property changes being sufficient to cause their formability to continue to be reduced. The advantage of -W temper formability can be utilized, however, in the same manner as with natural aging alloys, and that is by fabricating shortly after solution heat treatment, or retaining formability by the use of refrigeration.

Refrigeration retards the rate of natural aging. At 32° F, the beginning of the aging process is delayed for several hours, while dry ice (-50° to -100° F) retards aging for an extended period of time.

Table 5-2 illustrates the different temper designations assigned to aluminum alloys and gives an example of the alloys using these temper designations.

PRECIPITATON PRACTICES

The temperatures used for precipitation hardening depend upon the alloy and the properties desired, ranging from 240° to 460° F.

Table 5-2.—Temper designations for aluminum alloys

Designation	Condition indicated	Example
-F	As fabricated	3003-F
-0	Fully annealed	6061-0
-W	Unstable temper following solution heat treatment	7075-W
-H1	Strain hardened only	3003-H12
-H2	Strain hardened and then partially annealed	5052-H24
-H3	Strain hardened and then stabilized	5052-H36
-T	Heat treated to produce stable tempers other than -F and -0	
-T3	Solution heat treated and then cold worked	2024-T3
-T4	Solution heat treated	2024-T4
-T5	Artificially aged only	6063-T5
-T6	Solution heat treated and then artificially aged	7075-T6
-T7	Solution heat treated and then stabilized to control growth and distortion	7075-T7
-T8	Solution heat treated, cold worked, and then artificially aged	2024-T86
-T9	Solution heat treated, artificially aged, and then cold worked	6061-T91
-T10	Artificially aged and then cold worked	2014-T10

NOTE: A second number added to the -H designations above indicates the degree of strain hardening. The -T designations above may have one or more digits added to denote certain variations of the basic heat treatments described.

They should be controlled within a very narrow range (plus or minus 5°) to obtain best results.

The time at temperature is dependent upon the temperature used, the alloy, and the properties desired. It ranges from 6 to 24 hours. Increasing the aging temperature decreases the soaking period necessary for proper aging. However, a closer control of both time and temperature is necessary when using the higher temperatures.

After receiving the thermal precipitation treatment the material should preferably be air cooled to room temperature. Water quenching, while not necessary, produces no ill effects. Furance cooling has a tendency to produce overaging.

ANNEALING OF ALUMINUM ALLOYS

NONHEAT-TREATABLE ALLOYS

The nonheat-treatable alloys, such as 1100, 3003, 5052, and 5056, are annealed to remove the effects of strain hardening produced by cold work.

All of these alloys except 3003 are annealed by heating to 650°F and no higher than 775°F. A temperature of 775°F must be used for 3003 because of its higher recrystallization temperature and to insure a faster heating rate through the critical change in grain structure.

Heating Rate

The heating rate is critical for alloy 3003, a relatively fast rate being required to produce a fine grain material. The heating rate for the other nonheat-treatable alloys is not too important for general applications.

Temperature

The upper temperature limit for this class of alloys, with the exception of high-purity alluminum and alloy 5052, is not critical. The higher temperatures promote discoloration and increase the thickness of the oxide film on alloy 5052 which contains an appreciable amount of magnesium. Because of this, the maximum temperature employed for alloy 5052 is 700° F, when maximum drawability is desired. Optimum is 650°.

Time at Temperature

The time at temperature varies, depending upon the temperature, the type of anneal, the thickness of the material, the method of loading, and similar factors. Generally, the soaking period will vary from 1/2 to 2 hours. A 1-hour soak is widely employed.

Rate of Cooling

The rate of cooling is not an important factor although a rapid quench is definitely not recommended due to the quenching strains set up. Air cooling will generally be found entirely satisfactory.

HEAT-TREATABLE ALLOYS

The heat-treatable alloys are annealed to remove the effects of strain hardening produced by plastic deformation or to remove the effects of solution heat treatment.

To remove strain hardening due to cold work, a 1-hour soak at 640° to 660° F followed by air cooling is generally satisfactory. This practice is also satisfactory to remove the effects of heat treatment if the maximum degree of softness is not required.

To remove the effects of partial or full heat treatment, a 2-hour soak at 750° to 800° F, followed by a maximum cooling rate of 50° per hour to 500° F, is required to obtain maximum softness.

To remove the effects of solution heat treatment or hardening due to cold work, the high zinc-bearing alloy 7075 should be soaked 2 hours at 775° F, air cooled to 450°, and soaked 6 hours at 450°. The stabilizing temperature at 450° is necessary to precipitate the soluble constituents from solid solution.

The annealing of solution heat-treated material should be avoided whenever possible if subsequent forming and drawing operations are to be performed. If such operations are not severe, it is generally advantageous to repeat the solution heat treatment and form the material in the freshly quenched condition.

Heating Rate

A moderately fast heating rate, while not essential, is desirable. If slow heating rates are employed, diffusion of copper and other soluble constituents may be excessive in clad products. There may also be a slight tendency to produce a coarse grain size.

Temperature

The use of temperatures in excess of those recommended above should be avoided. As previously mentioned, this group consists of alloys that contain substantial amounts of soluble constituents. To obtain optimum workability, these constituents must be out of solution, uniformly distributed, and of optimum size.

Time at Temperature

The time at temperature varies, depending upon the temperature, the type of anneal, the material, and similar factors. Excessive time at temperature promotes grain growth, diffusion, and discoloration.

Cooling Rate

The cooling rate is important only if the annealing practices cause part of the soluble constituents to go into solution. When this occurs, the rate of cooling must be controlled.

HEAT TREATMENT OF ALUMINUM ALLOY RIVETS

Aluminum alloy rivets are furnished in the following compositions: Alloys 1100, 5056, 2117, 2017, and 2024.

Alloy 1100 rivets are used in the "as fabricated" condition for riveting aluminum alloy sheets where a low-strength rivet is suitable. Alloy 5056 rivets are used in the "as fabricated" condition for riveting magnesium alloy sheets.

Alloy 2117 rivets have moderately high strength and are suitable for riveting aluminum alloy sheets. These rivets receive only one heat treatment, which is performed by the manufacturer, and are anodized after being heat-treated. They require no further heat treatment before they are used. Alloy 2117 rivets retain their characteristics indefinitely after heat treatment and can be driven any time. Rivets made of this alloy are the most widely used in aircraft construction.

Alloy 2017 and 2024 rivets are high-strength rivets suitable for use with aluminum alloy structures. They are purchased from the manufacturer in the heat-treated condition. Since the aging characteristics of these alloys at room temperatures are such that the rivets are unfit for driving, they must be reheat-treated just before they are to be used. These rivets must be driven within 20 minutes after quenching or stored in a refrigerator at 32° F or lower which will delay the aging time 24 hours. Both of these alloys may be reheat-treated as often as required; however, rivets which have been anodically oxide-coated should not be reheat-treated in direct contact with molten salts more than 5 times.

RIVET HEAT TREATMENT PROCEDURES

Alloy 2017 Rivets

The heat treatment of alloy 2017 rivets consists of subjecting the rivets to a temperature between 930° to 950° F for approximately 30 minutes, and immediately quenching in cold water. The ultimate strength of these rivets reaches its maximum in about 4 days after being driven.

Alloy 2024 Rivets

Alloy 2024 rivets should be heat-treated to a temperature of 910° to 930° F and immediately quenched in cold water. These rivets develop a greater shear strength than 2017 rivets and are used in locations where extra strength is required. Alloy 2024 rivets develop their maximum shear strength in one day after being driven.

HEAT TREATMENT OF MAGNESIUM ALLOYS

Magnesium alloy castings respond readily to heat treatment, and about 95 percent of the magnesium used in aircraft construction is in the cast form.

The heat treatment of magnesium alloy castings is similar to the heat treatment of aluminum alloys in that there are two types of heat treatment–solution heat treatment and precipitation (aging) heat treatment. Magnesium, however, develops a negligible change in its properties when allowed to age naturally at room temperatures.

Solution heat treatment is given to magnesium alloy castings to improve tensile strength, ductility, and shock resistance. This heat-treatment condition is indicated by using the symbol -T4 following the alloy designation. Solution heat treatment plus artificial aging is designated -T6. Artificial aging is necessary to develop the full properties of the metal.

SOLUTION HEAT TREATMENT

Solution heat treatment temperatures for magnesium alloy castings range from 720° to 1055° F, the exact range depending upon the type of alloy.

The soaking time ranges from 2 to 24 hours, the exact time depending upon the type of alloy as well as the thickness of the part. Soaking periods longer than 24 hours may be necessary for castings over 2 inches in thickness.

Air cooling is used after solution heat treatment since there appears to be no advantage in liquid cooling.

PRECIPITATION HEAT TREATMENT

Precipitation heat treatment temperatures are considerably lower than the solution heat treatment temperatures and range from 265° to 650° F. Soaking time ranges from 2 to 48 hours.

Both the yield strength and hardness are improved somewhat by this treatment at the expense of a slight amount of ductility and toughness.

PRECAUTIONS

A serious potential fire hazard exists in the heat treatment of magnesium alloys. If, through oversight or malfunctioning of equipment, the maximum temperatures are exceeded, the casting may ignite and burn freely. For this reason the furnace used should be equipped with a safety cutoff which will turn off the power to the heating elements and blowers in the event of any malfunctioning or failure of the regular control equipment.

Magnesium alloys must never be heated in a salt bath. To do so may result in an explosion.

Some of the magneisum alloys require a protective atmosphere of sulfur dioxide gas during solution heat treatment. This aids in preventing the starting of a fire even when the temperature limits are slightly exceeded.

HEAT TREATMENT OF TITANIUM AND ITS ALLOYS

Titanium-bearing ores are plentiful, but the technical difficulties in recovering, melting, and processing the metal are severe. These difficulties make titanium costly; however, the desirable strength-weight ratio in the temperature range from 250° to 1,000° F has justified the use of the metal in many places in airframes and aircraft engines, even at prices 10 to 15 times as great as stainless steel.

Virtually all titanium is being used today because of its favorable strength-weight ratio in the above mentioned temperature range; however, it also has corrosion resistance equal or superior to 18-8 stainless steel, notable in marine atmospheres. This combination makes titanium especially adapted for use in naval aircraft.

AIRCRAFT USES

Titanium and titanium alloy sheet are being used in airframes for both structural and nonstructural applications, primarily surrounding engines, where service temperatures are in the range from 250° to 1,000° F. Aluminum alloys, are generally more efficient than titanium at temperatures below 250° and stainless steel is more efficient above 1,000° F.

The chief usage of titanium in jet engines is as bar stock and forgings. These are used in making compressor discs, spacer rings, rotating and stationary compressor blades and vanes, through bolts, turbine housings and liners, and miscellaneous hardware.

FORMING

In forming, unalloyed titanium behaves about like 1/4-hard 18-8 stainless steel; the presently available titanium alloys, in the annealed condition, are similar to 1/2-hard 18-8. Only with great difficulty can work-hardened titanium be formed by conventional methods.

Titanium is sensitive to rates of forming, and slow rates are preferred for maximum formability. The springback resulting from forming unalloyed titanium is approximately equal to that for 1/4-hard 18-8 stainless steel. In the available alloys, the springback is about 25 percent greater than with 1/2-hard 18-8 stainless steel.

Hot forming is used in producing smaller bend radii, increased elongation, and less springback. Any degree of heating is beneficial; however, unalloyed titanium is generally heated to 500° or 600° F, and the alloys are heated to a temperature of 800° to 1,000° F. Higher temperatures within the ranges mentioned are recommended for the more difficult forming jobs, but uniformity of heating is as important as a particular temperature level. Heating should not be prolonged unnecessarily because of danger of surface contamination by oxygen.

HEAT TREATMENT

Titanium is heat treated for the following reasons:

1. Relief of stresses set up during cold forming or machining.
2. Full annealing after hot working or cold working, or to provide maximum ductility for subsequent cold working.
3. Thermal hardening to improve strength.

STRESS RELIEVING

Stress relieving is generally used to remove stress concentrations resulting from forming of titanium sheet. The time at temperature varies from a few minutes for very thin sheet to an hour or more for heavier sections. A typical stress relieving treatment is 1,000° F for 30 minutes, followed by an air cool.

The discoloration or scale which forms on the surface of the metal during stress relieving is easily removed by pickling in acid solutions. The recommended solution contains 10 percent nitric acid and 2 percent hydrofluoric acid. The solution should be at a temperature of approximately 130° F.

FULL ANNEALING

The full anneal is usually called for as preparation for further working. The time at temperature varies from a few minutes to an hour, depending on the thickness of material and the amount of cold work to be performed. The usual treatment for the commonly used alloys is 1,300° F, followed by an air cool.

A full anneal generally results in sufficient scale formation to require the use of caustic descaling, such as sodium hydride.

THERMAL HARDENING

Unalloyed titanium cannot be heat treated, but the alloys commonly used in aircraft construction can be strengthened by thermal treatment, usually at some sacrifice in ductility.

CASEHARDENING

The chemical activity of titanium and its rapid absorption of oxygen, nitrogen, and carbon at relatively low temperatures make casehardening advantageous for special applications.

Nitriding

Nitriding in pure nitrogen is effective. Atmosphere is more efficient than dissociated ammonia. Case depth of 0.0035 inch has been obtained after 16 hours at 1,600° F.

Carburizing

Carburizing produces a wear-resistant case of 0.0001 to 0.0002 inch in depth. A mixture of

1/2 percent propane in argon at 1,750° to 1,800° F for 6 to 8 hours has been used successfully.

Carbonitriding

Carbonitriding produces some surface hardening after 30 minutes at 1,300° F. A mixture of propane, ammonia, and cracked propane is used in a ration of 2 percent, 33 percent, and 65 percent, respectively.

HEAT-TREATING EQUIPMENT

Successful heat-treating requires close control over all factors affecting the heating and cooling of metals. Such control is possible only when the proper equipment is available and the equipment is selected to fit the particular job. Thus, the furnace must be of the proper size and type and must be so controlled that temperatures are kept within the limits prescribed for each operation. Even the atmosphere within the furnace affects the condition of the part being heat-treated. Furthermore, the quenching equipment and the quenching medium must be selected to fit the metal and the heat-treating operation. Finally, there must be equipment for handling parts and materials, for cleaning metals, and for straightening parts.

FURNACES

Electric and fuel-fired furnaces are widely used in the heat treatment of both ferrous and nonferrous metals. Electric furnaces are heated by heating elements of the resistor type. Fuel-fired furnaces are named according to the type of fuel burned to produce heat. Fuels commonly used are oil, natural gas, and liquid petroleum gases such as butane and propane.

Heat-treating furnaces differ also in size, shape, capacity, construction, operation, and control. They may be circular or rectangular and may rest on pedestals or directly on the floor. There are also pit type furnaces, which are below the surface of the floor. When metal is to be heated in a bath of molten salt or lead, the furnace must contain a pot for the molten bath.

The size and capacity of a heat-treating furnace naturally depends on the intended use. A furnace must be capable of heating rapidly and uniformly regardless of the desired maximum temperature or the mass of the charge.

Figure 5-1 illustrates both the salt bath and oven type furnace.

Temperature in the heat-treated furnace is measured by a thermoelectric instrument known as a pyrometer. This instrument measures the electrical effect of a thermocouple and, hence, the temperature of the metal being heated. A complete pyrometer consists of three parts–a thermocouple, extension leads, and meter.

Pyrometers may have meters either of the indicating type or recording type. Indicating pyrometers (Fig. 5-2) give direct readings of the furnace temperature. The recording type (Fig. 5-3) produces a permanent record of the temperature range throughout the heating operation by means of an inked stylus attached to an arm.

Pyrometer installations on all modern furnaces provide automatic regulation of the temperature at any desired setting. Instruments of this type are called controlling potentiometer pyrometers. They include a current regulator and an operating mechanism such as a relay.

Three types of electric furnaces are currently available from Aviation Supply stock. A description of each type follows:

Box type, heavy duty with automatic temperature control, Brown controlling pyrometer. Oven size is 18 x 36 x 18 inches. Maximum operating temperature 2,000° F. Operates on 220-volt, 60-Hz alternating current, 33kw.

Basket type, automatic temperature control. Equipped with 15 small baskets for heat treating rivets. Maximum operating temperature, 1,250° F, 12kw.

Salt bath type (portable), recording and controlling potentiometer. Maximum operating temperature, 940° F, 6 kw. Equipped with 7 canisters for heat-treating small parts.

QUENCHING EQUIPMENT

The quenching tank should be of the proper size to handle the charge being quenched. Circulating pumps and coolers may be used to maintain approximately constant temperatures when a large amount of quenching is to be done. Provision must be made to add fresh water to the quench tank used in conjunction with molten salt baths, so as to avoid building up a high concentration of salt in the quenching tank.

Tank location in reference to the heat-treating furnace is very important. The tank should be situated to permit rapid transfer of the charge from the furnace to the quenching medium. A delay of more than a few seconds will in many instances prove detrimental to the effectiveness of the heat treatment. When material of thin section is being heat-treated, guard sheets should be employed to retard the loss of heat during transfer to the quench tank.

A rinse tank must be provided to remove all salt from the material after quenching, if the salt has been adequately removed in the quenching tank.

HARDNESS TESTING

Hardness testing is a method of determining the results of heat treatment as well as the state of a metal prior to heat treatment. Since hardness values can be tied in with tensile strength values and, in part, with wear resistance, hardness tests are an invaluable check of heat-treat control and of material properties.

Practically all hardness testing equipments now in use utilize the resistance to penetration as a measure of hardness. Included among the better known bench type hardness testers are the Brinell and Rockwell, both of which are described and illustrated in this section. Also included are three portable type hardness testers now being used by maintenance activities.

BRINELL TESTER

The Brinell tester (Fig. 5-4) uses a hardened spherical ball which is forced into the surface of the metal. The ball is 10 millimeters (0.3937 inch) in diameter. A pressure of 3,000 kilograms (6,600 pounds) is used for ferrous metals and 500 kilograms for nonferrous metals. Normally, the load should be applied for 30 seconds. In order to produce equilibrium, this period may be increased to 1 minute for extremely hard steels. The load is applied by means of hydraulic pressure. The hydraulic pressure is built up by a hand pump or an electric motor, depending on the model of tester. A pressure gage indicates the amount of pressure. There is a release mechanism for relieving the pressure after the test has been made, and a calibrated microscope is provided for measuring the diameter of the impresson in millimeters. The machine has various shaped anvils for supporting the specimen and an elevating screw for bringing the specimen in contact with the ball penetrator. There are attachments for special tests.

In order to determine the Brinell hardness number for a metal, the diameter of the impression is first measured, using the calibrated microscope furnished with the tester. Figure 5-5 illustrates an impression as seen through the microscope. After measuring the diameter of the impression, the measurement is converted into the Brinell hardness number on the conversion table furnished with the tester. A portion of the conversion table is shown in Table 5-3.

ROCKWELL TESTER

The Rockwell hardness tester (Fig. 5-6) measures the resistance to penetration as does the Brinell tester, but instead of measuring the diameter of the impression, the Rockwell tester measures the depth, and the hardness is indicated directly on a dial attached to the machine. The shallower the penetration, the higher is the hardness number.

Two types of penetrators are used with the Rockwell tester, one being a diamond cone, the

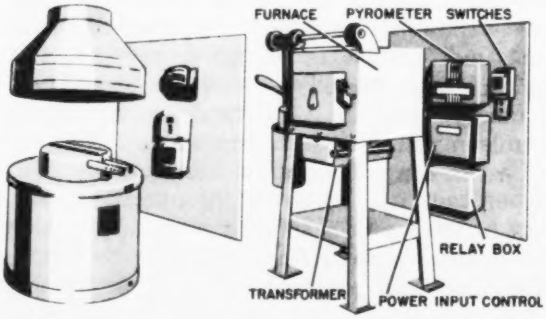


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Figure 5-1.—Heat-treating furnaces.

other a hardened steel ball. The load which forces the penetrator into the metal is called the major load and is measured in kilograms. The results of each penetrator and load combination are reported on separate scales, designated by letters. The penetrator, the major load, and the scale vary with the kind of metal being tested.

For hardened steels, the diamond penetrator is used, the major load is 150 kilograms, and the hardness is read on the C scale. When this reading is recorded, the letter C must precede the number indicated by the pointer. The C scale setup is used for testing metals ranging in hardness from C-20 to the hardest steel (usually about C-70). If the metal is softer than C-20, the B-scale setup is used. With this setup, the 1/16-inch ball is used as a penetrator, the major load is 100 kilograms, and the hardness is read on the B-scale.

In addition to the C and B scales, there are other setups for special testing. The scales, penetrators, major loads, and dial numbers to be read are listed in Table 5-4. The dial numbers in the outer circle are black, and the inner numbers are red.

The Rockwell tester is equipped with a weight pan, and two weights are supplied with the machine. One weight is marked in red. The other weight is marked in black. With no weight in the weight pan, the machine applies a major load of 60 kilograms. If the scale setup calls for a 100-kilogram load, the red weight is placed in the pan. For a 150-kilogram load, the black weight is added to the red weight. The black weight is always used in conjunction with the red weight; it is never used alone.

Practically all testing is done with either the B-scale setup or the C-scale setup. For these scales, the colors may be used as a guide in selecting the weight (or weights) and in reading the dial. For the B-scale test, use the red weight and read the red numbers. For a C-scale test, add the black weight to the red weight and read the black numbers.

In setting up the Rockwell machine, use the diamond penetrator for testing materials which are known to be hard. If in doubt, try the diamond, since the steel ball may be deformed if used for testing hard materials. If the metal tests below C-22, then change to the steel ball.

Use the steel ball for all soft materials–those testing less than B-100. Should an overlap occur at the top of the B scale and the bottom of the C scale, use the C-scale setup.

Before the major load is applied, the test specimen must be securely locked in place to

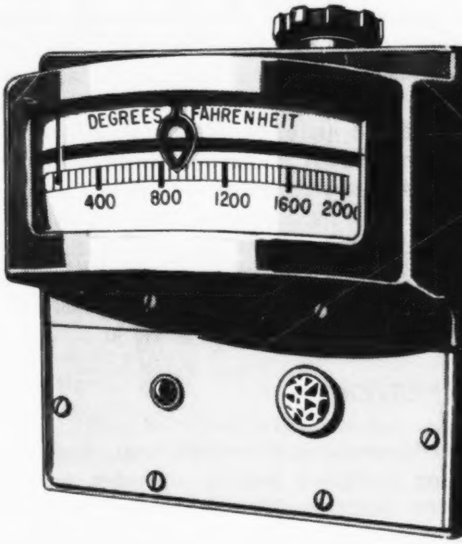

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Figure 5-2.–Indicating pyrometer.

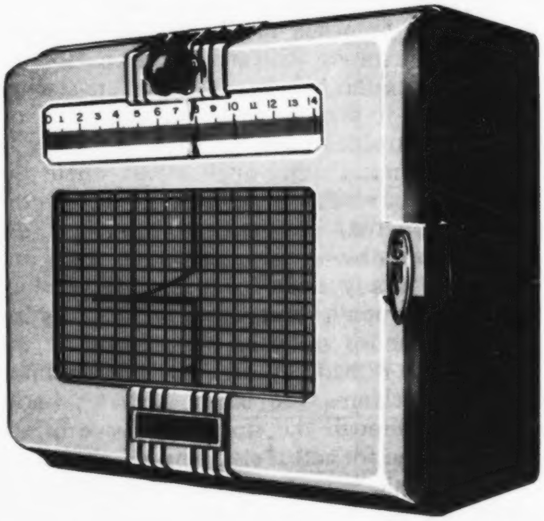

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Figure 5-3.–Recording pyrometer.

prevent slipping and to properly seat the anvil and penetrator. To do this, a load of 10 kilograms is applied before the lever is tripped. This preliminary load is called the minor load. The minor load is 10 kilograms regardless of the scale setup. When the machine is set up properly, it automatically applies the 10-kilogram load.

The metal to be tested in the Rockwell tester must be ground smooth on two opposite sides and be free of scratches and foreign matter. The surface should be perpendicular to the axis of penetration, and the two opposite ground surfaces should be parallel. If the specimen is tapered, the amount of error will depend on the taper. A curved surface will also cause a slight error in the hardness test. The amount of error depends on the curvature—the smaller the radius of curvature, the greater the error. To eliminate such error, a small flat should be ground on the curved surface if possible.

RIEHLE TESTER

The Riehle tester is a portable unit, designed for making Rockwell tests comparable to the bench type machine. The instrument is quite universal in its application, being readily adjustable to a wide range of sizes and shapes which would be difficult, or impossible, to test on a bench type tester.

Figure 5-7 illustrates the tester and its proper use. It may be noted that the adjusting screws and the penetration indicator are set back some distance from the penetrator end of the clamps. This makes it practicable to use the tester on either the outside or inside surface of tubing as well as on many other applications where the clearance above the penetrator or below the anvil is limited. The indicator brackets are arranged so that it is possible to turn the indicators to any angle for greater convenience in a specific application, or to facilitate its use by a left-handed operator. Adjustment of the lower clamp is made by the small knurled knob below the clamp. The larger diameter knob, extending through the slot in the side of the clamp, is used for actual clamping.

Each Riehle tester is supplied with a diamond penetrator and a 1/16-inch ball penetrator. The ball penetrator should not be used on materials harder than B-100, nor on a load heavier than 100 kilograms. This is to avoid the danger of flattening the ball.

The diamond penetrator, when used with a 150-kilogram load, may be used on materials from the hardest down to those giving a reading of C-20.

When the expected hardness of a material is completely unknown to the operator, it is advisable to take a preliminary reading on the A

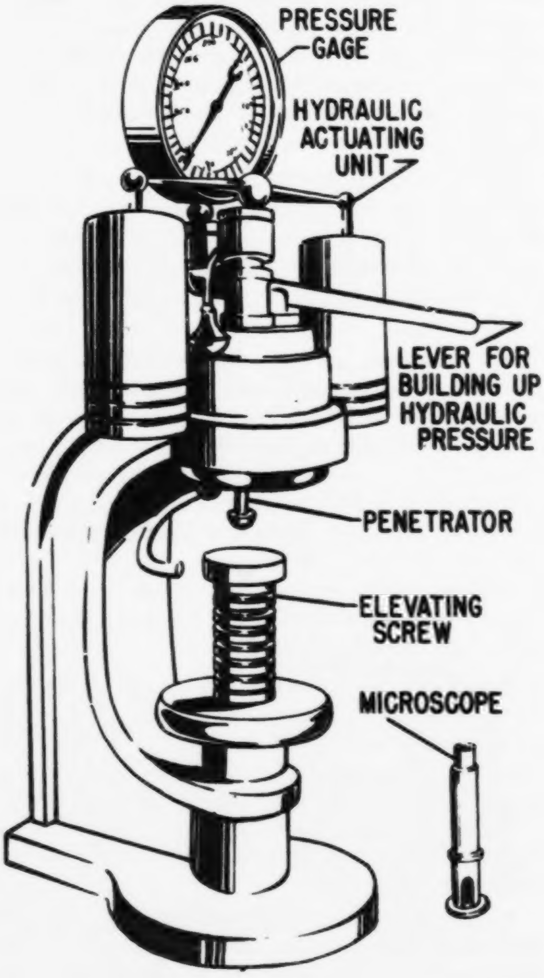

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Figure 5-4.—Brinell hardness tester.

scale as a guide in selecting the proper scale to be used.

Testing Procedure

The basic procedure in making a test with the Riehle tester is as follows:

1. Apply a minor load of 10 kilograms.
2. Set the penetration indicator to zero.
3. Apply a major load of 60, 100, or 150 kilograms (depending on the scale), and then reduce the load back to the initial 10-kilogram load.
4. Read the hardness directly on the penetration indicator. The hardness reading is based on the measurement of the additional increment of penetration produced by applying a major load after an initial penetration has been produced by the minor load. In reporting a hardness number, the number must be prefixed by the letter indicating the scale on which the reading was obtained.

Removal and Replacement of Penetrator

The penetrator is retained in the tester by means of a small knurled clamp screw extending from the top of the upper clamp. To remove a penetrator, there should be at least 2 or 3 inches of space between the upper and lower clamps so that one hand can be placed underneath the upper clamp to catch the penetrator when it is released. Two or three turns of the clamp screw will release the penetrator. The two contact pins which extend through the penetrator on either side of the point are retained in the tester when the penetrator is removed

To replace a penetrator, it must be turned so that the flat side faces the clamp screw, and the locating pin on the penetrator is in line with the slot provided to take the pin. The contact pins should be guided into their respective holes through the penetrator. With the penetrator in place, it should then be clamped securely by turning the clamp screw. Before making an actual test, one or two preliminary tests should be made to properly seat the penetrator.

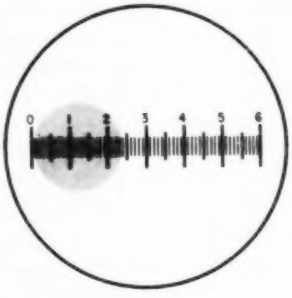

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Figure 5-5.–Microscopic view of impression.

Table 5-3.–Portion of conversion table furnished with Brinell tester

Diameter of ball impression (mm)	Hardness number for load of kg	
	500	3000
2.0	158	945
2.05	150	899
2.10	143	856
2.15	136	817
2.20	130	780
2.25	124	745
2.30	119	712
2.35	114	682
2.40	109	653
2.45	100	627

Table 5-4.—Standard Rockwell hardness scales

Scale symbol	Penetrator	Major load (kg.)	Dial number
A	Diamond	60	Black
B	1/16-inch ball	100	Red
C	Diamond	150	Black
D	Diamond	100	Black
E	1/8-inch ball	100	Red
F	1/16-inch ball	60	Red
G	1/16-inch ball	150	Red
H	1/8-inch ball	60	Red
K	1/8-inch ball	150	Red

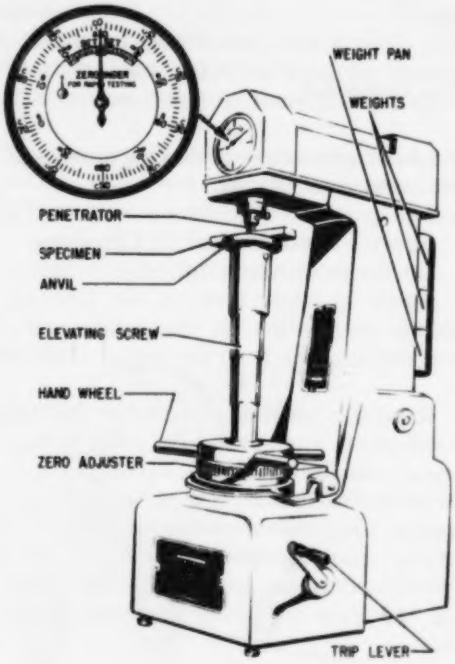

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Figure 5-6.—Rockwell hardness tester.

BARCOL TESTER

The Barcol tester (Fig. 5-8) is a portable unit designed for testing aluminum alloys, copper, brass, and other relatively soft materials. Approximate range of the tester is 25 to 100 Brinell. The unit can be used in any position and in any space that will allow for the operator's hand. The hardness is indicated on a dial conveniently divided in 100 graduations.

Figure 5-9 is a cutaway drawing of the tester, showing the internal parts and their general arrangement within the case.

The lower plunger guide and point are accurately ground so that attention need be given only to the proper position of the lower plunger guide within the frame in order to obtain accurate operation when a point is replaced.

The frame, into which the lower plunger guide and spring tensioned plunger are screwed, holds the point in the proper position. Adjustment of the plunger upper guide nut, which regulates the spring tension, is made when the instrument is calibrated at the factory; THE POSITION OF THIS NUT SHOULD NOT BE CHANGED.

The leg is set for testing surfaces which permit the lower plunger guide and the leg plate to be on the same plane. For testing rivets or other raised objects, a block may be placed under the leg plate to raise it to the same plane. For permanent testing of this type, the leg may be removed and washers inserted, as shown in the drawing. The point should always be perpendicular to the surface being tested.

Testing Procedure

The design of the Barcol tester is such that operating experience is not necessary. It is only necessary to exert a light pressure against the instrument to drive the spring-loaded indenter into the material to be tested. The hardness reading is instantly indicated on the dial. Several typical readings for aluminum alloys are listed in

Table 5-5. Note that the harder the material, the higher is the Barcol number.

To prevent damage to the point, avoid sliding or scraping when it is in contact with the material being tested. If the point should become damaged, it must be replaced with a new one. No attempt should be made to grind the point.

Each tester is supplied with a test disc for checking the condition of the point. To check the point, press the instrument down on the test disc. When the downward pressure brings the end of the lower plunger guide against the surface of the disc, the indicator reading should be within the range shown on the test disc.

To replace the point, remove the two screws which hold the halves of the case together. Lift out the frame, remove the spring sleeve, loosen the locknut and unscrew the lower plunger guide, holding the point upward so that the spring and plunger will not fall out of place. Insert new point and replace lower plunger guide, screwing it back into the frame. Adjust the lower plunger guide with the wrench that is furnished until the indicator reading and the test disc average number are identical. After the lower plunger guide is properly set, tighten the locknut to keep the lower plunger guide in place. This adjustment should be made only after installing a new point; any readjustment on a worn or damaged point give erroneous readings.

ERNST TESTER

The Ernst tester is a small versatile tool which requires access to only one side of the material being tested. There are two models of the tester–one for testing hardened steels and hard alloys, the other for testing unhardened steels and most nonferrous metals. It has a diamond point penetrator, and it is read directly from the Rockwell A or B, or the Brinell scales, depending on the model used. Figure 5-10 illustrates the Ernst tester and its proper use.

Testing Procedure

1. Solidly support the metal being tested by placing a bucking bar behind the metal. This will minimize flexure of the metal and yield a more accurate reading of hardness.

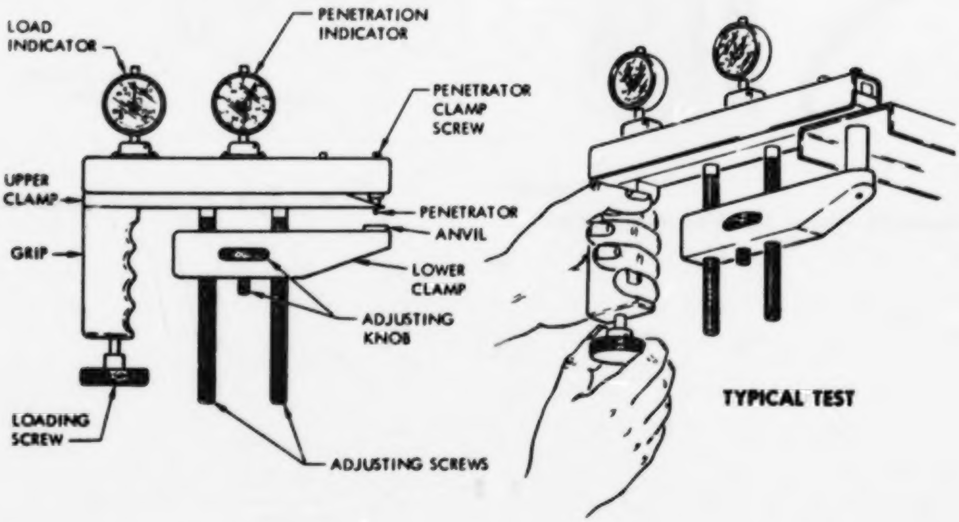

Figure 5-7.—Riehle portable hardness tester.

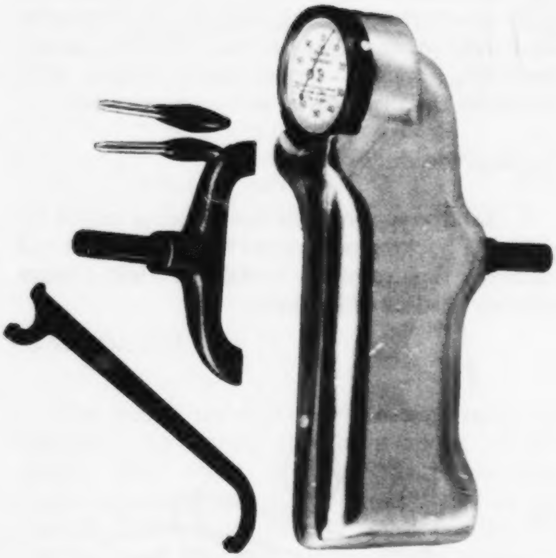

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Figure 5-8.—Barcol portable hardness tester.

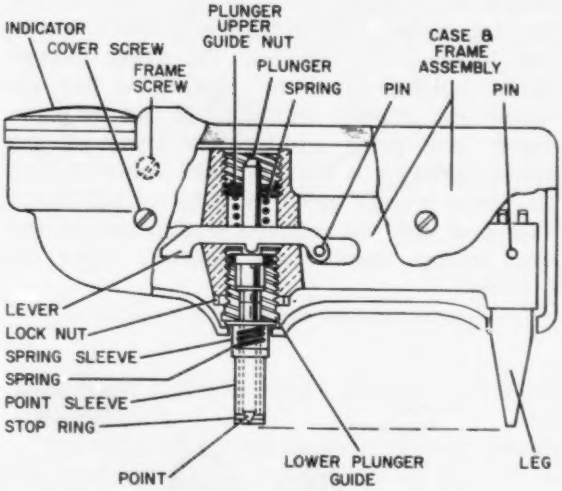
INDICATOR
COVER SCREW
FRAME SCREW
PLUNGER UPPER GUIDE NUT
PLUNGER
SPRING
PIN
CASE & FRAME ASSEMBLY
PIN
LEVER
LOCK NUT
SPRING SLEEVE
SPRING
POINT SLEEVE
STOP RING
POINT
LOWER PLUNGER GUIDE
LEG

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Figure 5-9.—Cutaway of Barcol tester.

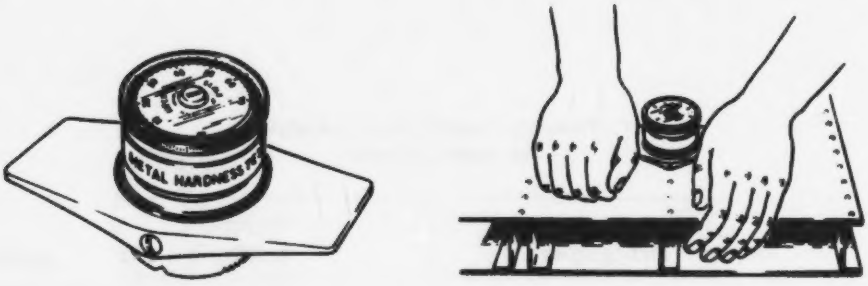
Table 5-5–Typical Barcol readings for aluminum alloys

Alloy and temper	Barcol number
1100-0	35
3003-0	42
3003-1/2H	56
2024-0	60
5052-0	62
5052-1/2H	75
6061-T	78
2024-T	85

2. The handgrip must be pressed down with a steady, even force to insure accurate readings.

3. Press down until the fluid column has stopped moving. The hardness value is given at the point where the fluid column has stopped moving on the scale.

As with other portable testers of similar type, the material must be smooth and backed up so there will be no tendency to sag under the load applied on the tester. The test block supplied with each tester should be used frequently to check its performance.



THE ERNST PORTABLE HARDNESS TESTER HAS A DIAMOND-TIPPED PENETRATOR AND READS IN ROCKWELL OR BRINELL SCALES

NOTE:
MATERIAL MUST BE SOLIDLY SUPPORTED FROM BEHIND. PRESS DOWN WITH A STEADY, EVEN FORCE.

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Figure 5-10.—Ernst portable hardness tester.

[illegible]

[illegible]

[illegible]

[illegible]

CHAPTER 7

NONDESTRUCTIVE INSPECTION OF METALS

Nondestructive inspection (NDI) of metal is a general term applied to a variety of methods used to determine the integrity of aircraft structures and components without adversely affecting the usefulness of the structure or component.

Aircraft parts are subjected to repeated stresses and in some instances overstress, which can result in fatigue failure. Failures can generally be related to design deficiency, material failure, or accidental overstress. The nondestructive inspection methods covered in this chapter serve as tools of prevention which allow defects to be detected before they develop into serious failures.

MAGNETIC PARTICLE INSPECTION

Magnetic particle inspection is a method of detecting invisible cracks and other defects in magnetic materials. The method is specifically applicable to ferromagnetic metals such as iron and low-carbon steels, which can be easily magnetized. Magnetic particle inspection has proved extremely reliable for the rapid detection of defects on or near the surface. In using this method of inspection, the location of the defect is indicated and the approximate size and shape are outlined.

The inspection process consists of magnetizing the part and then applying ferromagnetic particles to the surface of the part. If a discontinuity is present, the magnetic lines of force will be disturbed and opposite poles will exist on either side of the discontinuity. The magnetized particles thus form a pattern in the magnetic field between the opposite poles. This pattern, known as an "indication," assumes the approximate shape of the surface projection of the discontinuity.

The ferromagnetic particles (indicating medium) may be held in suspension in a liquid that is flushed over the part, the part may be immersed in the suspension, or the particles, in dry powder form, may be dusted over the surface of the part. The wet process is more commonly used in the inspection of aircraft parts.

NOTE: A discontinuity may be defined as an interruption in the normal physical structure or configuration of a part such as a crack, forging lap, seam, inclusion, porosity, and the like. A discontinuity may or may not affect the usefulness of a part.

DEVELOPMENT OF INDICATIONS

When a discontinuity in a magnetized material is open to the surface and a magnetic substance in the form of an indicating medium is available on the surface, the flux leakage at the discontinuity tends to form the indicating medium into a path of higher permeability. (Permeability is a term used to refer to the ease with which a magnetic flux can be established in a given magnetic circuit.) Because of the magnetism in the part and the adherence of the magnetic particles to each other, the indication remains on the surface of the part in the form of an approximate outline of the discontinuity that is immediately below it.

The same action takes place when the discontinuity is not open to the surface, but since the amount of flux leakage is less, fewer particles are held in place and a fainter and less sharply defined indication is obtained.

If the discontinuity is very far below the surface, there may be no flux leakage and therefore no indication on the surface. The flux leakage at a transverse discontinuity is shown in Figure 7-1. The flux leakage at a longitudinal discontinuity is shown in Figure 7-2.

TYPES OF DISCONTINUITIES DISCLOSED

The following types of discontinuities are normally detected by the magnetic particle test: cracks, laps, seams, cold shuts, inclusions, splits, tears, pipes, and voids. All these may affect the reliability of parts in service.

Cracks, splits, bursts, tears, seams, voids, and pipes are formed by an actual parting or rupture of the solid metal. Cold shuts and laps are folds that have been formed in the metal, interrupting its continuity.

Inclusions are foreign material formed by impurities in the metal during the metal processing stages. They may consist, for example, of bits of furnace lining picked up during the melting of the basic metal, or of other foreign constituents. Inclusions interrupt the continuity of the metal because their presence prevents the joining or welding of adjacent faces of the metal.

PREPARATION OF PARTS FOR TESTING

All parts must be cleaned of grease, oil, and dirt before they are tested. Cleaning is important, since any grease or other foreign material present may produce nonrelevant indications by reason of magnetic particles adhering to the foreign material as the suspension drains from the part.

Grease or foreign material in sufficient amount over a discontinuity may also prevent the formation of a pattern at the discontinuity. It is not advisable to depend upon the magnetic particle suspension to clean the part. Cleaning by the suspension will not be thorough, and the foreign materials removed from the part will contaminate the suspension and reduce its effectiveness.

In the dry procedure, thorough cleaning is very necessary as grease or other foreign material will hold the magnetic powder, causing nonrelevant indications and making it impossible to evenly distribute the indicating medium over the surface of the part.

All small openings and oil holes leading to obscure passages or cavities should be plugged with paraffin or other suitable nonabrasive material.

Primers, paints, enamels, and similar nonmetallic coatings, as well as coatings of cadmium, copper, tin, and zinc do not interfere with the satisfactory performance of magnetic particle inspection, unless the coatings are unusually heavy, or the discontinuities to be detected are unusually small.

Chromium and nickel plating will not generally interfere with the formation of indications of cracks open to the surface of the base metal, but will prevent the formation of indications of fine discontinuities, such as inclusions. Because it is more strongly magnetic, nickel plating is more

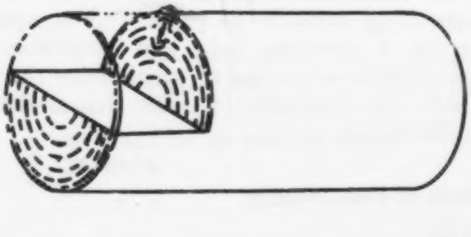
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Figure 7-1.–Flux leakage at transverse discontinuity.

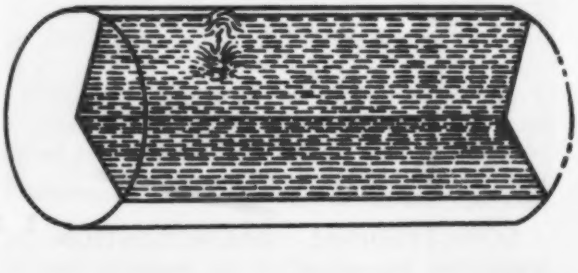
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Figure 7-2.–Flux leakage at longitudinal discontinuity.

effective than chromium plating in preventing the formation of indications.

MAGNETIZATION

Effect of Direction of Flux (Lines of Force)

In order to locate a defect in a part it is essential that the magnetic lines of force pass approximately perpendicular to the defect. It is therefore necessary to induce magnetic flux in more than one direction since defects are likely to exist at any angle to the major axis of the part. This requires two separate magnetizing operations, referred to as circular magnetization and longitudinal magnetization. The effect of direction of flux is illustrated in Figure 7-3.

CIRCULAR MAGNETIZATION.–Circular magnetization is the inducing of a magnetic field consisting of concentric circles of force about and within the part by passing electric current through the part. This type of magnetization will locate defects running approximately parallel to the axis of the part.

Circular magnetization of a part of solid cross section is illustrated in Figure 7-4. Each head of the magnetizing unit is electrically connected to a pushbutton control, so that when contact is made the magnetizing current passes from one head to the other through the part.

Electric currents passed through hollow or tubelike parts circularly magnetize them but do not produce satisfactory magnetic fields on the inside surfaces. Satisfactory fields can be induced by sliding the part onto a conductor. Current passes through the conductor and induces circular magnetic fields on both inside and outside cylindrical surfaces as illustrated in Figure 7-5.

Circular fields can also be induced in localized areas of parts by using cables and probes or contacts to pass current through the area being inspected as illustrated in Figure 7-6.

LONGITUDINAL MAGNETIZATION.–In logitudinal magnetization the magnetic field is produced in a direction parallel to the long axis of the part. This is accomplished by placing the part in a coil excited by electric current. The metal part then becomes the core of an electromagnet and is magnetized by induction from the magnetic field created in the coil.

In longitudinal magnetization of long parts, the coil must be moved along the part in order to magnetize it in appropriate lengths. (See Fig. 7-7.) This is necessary to insure adequate field strength throughout the entire length of the part.

Coils produce effective magnetization for approximately 6 to 9 inches from each end of the coil. When inspecting a long part, it will be necessary to magnetize and inspect it in sections along the entire length of the part.

Longitudinal magnetization equivalent to that obtained by a coil may be accomplished by wrapping a flexible electrical conductor around the part, as shown in Figure 7-8. Although this method is not as convenient, it has the advantage that the coils conform more closely to the shape of the part, thus producing somewhat more uniform magnetization.

The flexible coil method is also useful for large or irregularly shaped parts for which standard coils are not available.

A longitudinal magnetic field can be induced in a part, or in an area of a part, by means of a yoke. A yoke is a "C" shaped piece of magnetic material, either solid or laminated, around which is wound a coil carrying the magnetizing current. When a part is placed across the opening of the "C" and the coil is energized, the part completes the path of the magnetic lines of force and sets up a longitudinal field in the part between the ends of the "C." The Parker Contour Probe discussed later in this chapter illustrates the practicality of this method of magnetizing parts.

Specially designed equipment is also available for the simultaneous application of two or more magnetizing currents to parts. This equipment sets up a swinging field and eliminates the time-consuming process of magnetizing the part in different directions to insure that all defects are discovered.

Effect of Flux Density

The effectiveness of the magnetic particle inspection also depends on the flux density or field strength that exists at the surface of the part when the indicating medium is applied. As the flux density in the part is increased, the sensitivity of the test increases because of the greater flux leakages at discontinuities and the resulting improved formation of magnetic particle patterns.

Excessively high flux densities, however, may form nonrelevant indications; for example, patterns of the grain flow in the material. These indications will tend to interfere with the detection of patterns resulting from significant discontinuities. It is therefore necessary to use a field strength high enough to reveal all possible harmful discontinuities, but not strong enough to produce confusing nonrelevant indications.

Recommended values for most parts are 800 to 1,000 amperes for each inch of cross section. For example, if a cylindrical part is 1 inch in diameter, an amperage of 800 to 1,000 should be passed through the part.

Magnetizing Methods

When a part is magnetized, the field strength in the part increases to a maximum for the particular magnetizing force and remains at this maximum as long as the magnetizing force is maintained.

When the magnetizing force is removed, the field strength decreases to a lower residual value, depending on the magnetic properties of the material and the shape of the part. These magnetic characteristics determine whether the continuous or residual method is used in magnetizing the part.

CONTINUOUS METHOD.–In the continuous inspection method, the indicating medium is on the part while the magnetizing current is flowing. The available flux density in the part is thus at a maximum. The maximum value of flux depends directly upon the magnetizing force and the permeability of the material of which the part is made.

When using the wet continuous method, the indicating medium bath is liberally applied to all surfaces of the part. The instant that the bath stream is removed from the part, the magnetizing

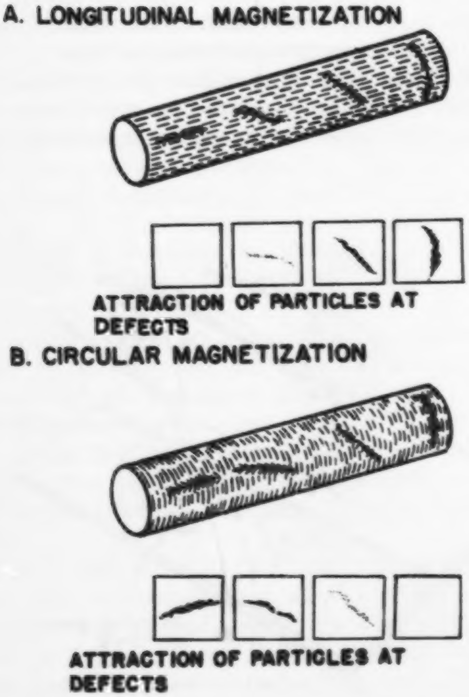
A. LONGITUDINAL MAGNETIZATION
ATTRACTION OF PARTICLES AT DEFECTS
B. CIRCULAR MAGNETIZATION
ATTRACTION OF PARTICLES AT DEFECTS

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Figure 7-3.–Effect of direction of flux on strength of indication.

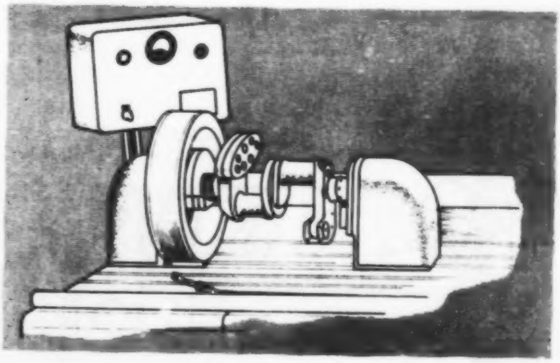

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Figure 7-4.–Circular magnetization of crankshaft.

force is applied; this insures that the indicating medium will be on the part while the current is flowing so the particles can be attracted to any leakage fields created by discontinuities. If the wet bath is applied during or after the magnetizing force there is a possibility that the force of the bath stream may wash off lightly held indications.

When the dry continuous method is used the part is magnetized using prods, clamps, or a coil. While the current is flowing the powder is applied to the magnetized area in a light cloud and the excess powder is blown off with a light airstream. After the excess powder is removed, the magnetizing current is shut off.

The continuous procedure provides greater sensitivity than the residual procedure, particularly in locating subsurface discontinuities. The highly critical nature of aircraft parts and assemblies and the necessity for subsurface inspection in many applications have resulted in the continuous method being more widely used by naval air activities.

Inasmuch as the continuous procedure will reveal more nonsignificant discontinuities than the residual procedure, careful and intelligent interpretation and evaluation of discontinuities revealed by this procedure are necessary.

RESIDUAL METHOD.–The residual inspection procedure involves magnetization of the part and application of the indicating medium after the magnetizing force has been removed. This procedure relies on the residual or permanent magnetism in the part and is more practical than the continuous procedure when magnetization is accomplished by flexible coils wrapped around the part. However, it must be remembered that residual fields are always weaker than magnetic fields which are present when the current is flowing. Consequently, inspection with the residual method will not be as sensitive as with the continuous method.

Identification of Indications

The correct evaluation of the character of indications is extremely important, but is sometimes difficult to make from observation of the appearance of the indications alone. The principal distinguishing features of indications are shape, buildup, width, and sharpness of outline. These characteristics, in general, are more valuable in distinguishing between types of discontinuities than in determining their severity. However, careful observation of the character of the magnetic particle pattern should always be included in the complete evaluation of the significance of an indicated discontinuity.

CRACKS.–The most readily distinguished indications are those produced by cracks open to the surface. These discontinuities include fatigue

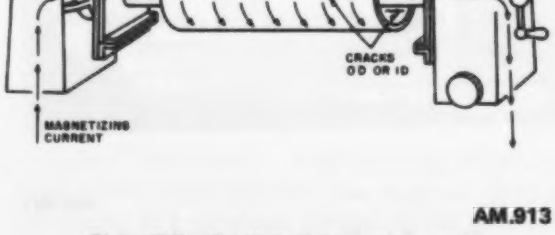

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Figure 7-5.—Conductor used to circularly magnetize a cylinder.

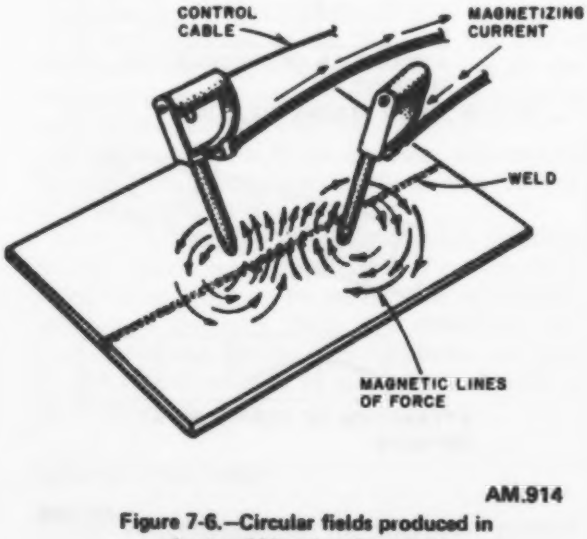

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Figure 7-6.—Circular fields produced in sheet weld by electric current passed between contact prods.

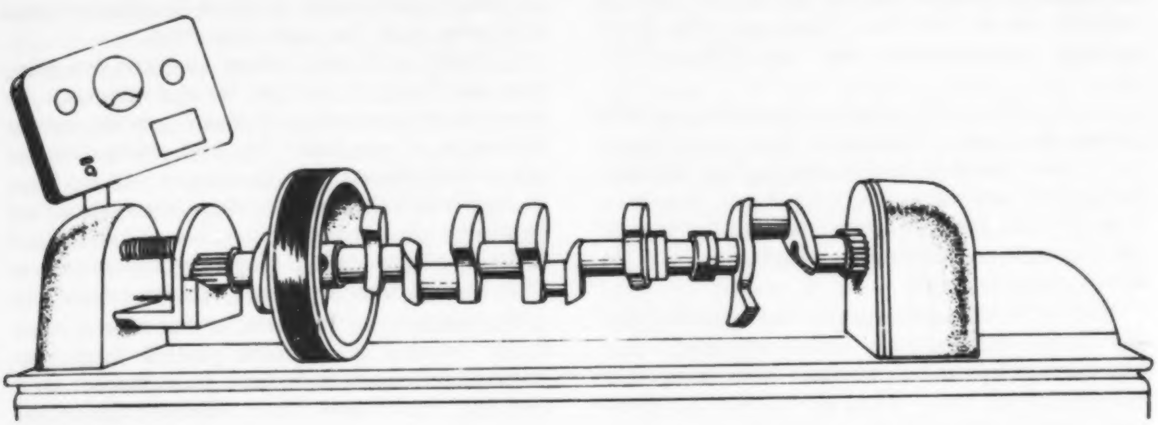

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Figure 7-7.–Longitudinal magnetization of crankshaft. (Coil method.)

cracks, heat-treat cracks, shrink cracks in welds and castings, and grinding cracks.

FATIGUE CRACKS give sharp, clear patterns, generally uniform and unbroken throughout their length and with good buildup. They are often jagged in appearance as compared with the straight indications of a seam and may also change direction slightly in localized areas. Figure 7-9 illustrates a fatigue crack in a crankshaft. Figure 7-10 illustrates a fatigue crack in a gear.

Fatigue cracks are found in parts that have been in service, but are never found in new parts. They are usually in high stressed areas of the part, or where a stress concentration exists for some reason. It is important to recognize that even a small fatigue crack indicates positively that failure of the involved part is in progress.

HEAT-TREAT CRACKS have smooth outline, but are usually less clear and have less buildup than fatigue cracks. On thin sections, such as cylinder barrel walls, heat-treat cracks may give very heavy patterns (Fig. 7-11). These heat-treat cracks have a characteristic form, consisting of short jagged lines grouped together.

SHRINK CRACKS give a sharp clear pattern and the line is usually very jagged. Since the walls of shrink cracks are close together, their indications generally build up to less extent than do indications of fatigue cracks. (See Fig. 7-12.)

GRINDING CRACKS are fine and sharp, but seldom have a buildup because of their limited depth. Grinding cracks vary from single line indications to a heavy network of lines. Grinding cracks are generally related to the direction of grinding. For example, the crack usually begins and continues at right angles to the motion of a grinding wheel, giving a rather symmetrical pattern. Indications of grinding cracks can frequently be identified by means of this relation.

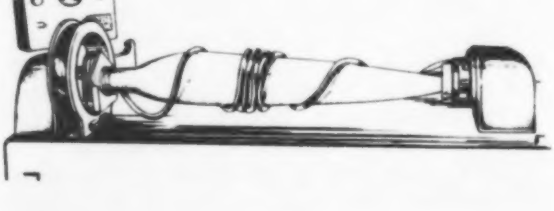

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Figure 7-8.–Longitudinal magnetization of steel propeller blade. (Cable method.)

SEAMS.–Indications of seams are usually straight, sharp, and fine. They are often intermittent and sometimes have very little buildup. (See Fig. 7-13.)

HAIRLINES.–Hairlines are very fine seams in which the faces of the seam have been forced very close together during fabrication. Hairline indications are very fine and sharp, and have very little buildup. Discontinuities of this type are normally considered detrimental only in highly stressed parts.

INCLUSIONS.–Inclusions are nonmetallic materials, such as slag, unruly materials, and chemical compounds, that have been trapped in the solidifying ingot. They are usually elongated and strung out as the ingot is worked in subsequent processing operations.

Inclusions appear in parts in varying sizes and shapes, from stringers easily visible to the eye to particles only visible under magnification. In a finished part they may occur as either surface or subsurface discontinuities.

Indications of subsurface inclusions are usually broad and fuzzy. They are seldom continuous or of even width and density throughout their length. Larger inclusions, particularly those near or open to the surface, appear more clearly defined. Close examination, however, will generally reveal their lack of definition and the fact that the indication consists of several parallel lines rather than a single line. These characteristics will usually distinguish a heavy inclusion from a crack.

PIPES AND DEEP SEATED CAVITIES.–When pipes or other cavities are located considerably below the surface of a part, the magnetic particle test is not a reliable method of detecting them. If any indication is obtained, it is likely to be an indistinct and inexact outline of the cavity, with the magnetic substance tending to distribute over the whole area rather than to outline clearly the boundary of the discontinuity. Defects of this type are better detected by radiographic procedures.

LAPS.–Laps may be identified by their form and location. They tend to occur at the points of maximum flow of metal; for example, at the ends or flash line of a forging. The indications are usually heavy and irregular. Islands and short branch indications usually break a lap indication of any length, and the scale included in the lap invariably gives fuzzy or small fern-like patterns stemming from the main indication.

SEGREGATIONS.–When an ingot solidifies, the distribution of the various elements or compounds generally is not uniform throughout the mass of the ingot. Marked segregations of some constituents may thus occur. As the ingot is forged and then rolled, these segregations are elongated and reduced in cross section. Upon subsequent processing, they may appear as very thin parallel lines or bands, known as banding.

Segregation in the form of banding is sometimes revealed by magnetic particle inspection, particularly when high field strengths are used. Banding is not normally considered significant.

The most serious forms of segregations probably occur in castings. Here, the basic condition of the metal remains unaltered in the finished part, and any segregations occur as they were originally formed. They may vary in size and will normally be irregular in shape. They may occur on or below the surface.

INCOMPLETE WELD PENETRATION.–Using magnetic particles, it is possible to find porosity, slag inclusions, shrink cracks, inadequate penetration, and incomplete fusion. Selective use of magnetizing currents is necessary so that both surface and sub-surface discontinuities are revealed. Inadequate penetration is generally revealed as a broad and fuzzy pattern.

GENERAL INTERPRETATION CONSIDERATIONS.–Negative results, those showing no magnetic particles clinging to the surface areas of the materials being tested, indicate a freedom from defects insofar as the magnetic particle test can determine.

A positive result, showing accumulation of particles over one or more surface areas, requires interpretation that the indication reveals a defect or is nonrelevant. In making this determination, the inspector must consider the material of which the part is made, part processing methods, heat-treating operations, and finishing operations. The inspector familar with these areas will be aware of the types of defects the various metals and processes can introduce and will know in advance what defects may be present.

Nonrelevant Indications

Some indications revealed by the magnetic particle inspection reveal design features or other insignificant characteristics such as variation in material, sharp edges, etc. Recognition of nonrelevant indications can be accomplished by the reinspection of the part using a lowered current setting, relating the indication to some feature of construction or cross section that accounts for a flux leakage, determining if the part was overmagnetized during the inspection, etc. Some nonrelevant indications are identified in Table 7-1. The ability to recognize indications of actual discontinuities, so as to identify them definitely, will depend on the inspector's experience level. Supplemental tests, including direct surface inspection, reinspection, inspection with magnifying viewing instruments, etc., will aid the inspector in verifying his results until he has gained adequate experience. NavAir 01-1A-16, Technical Manual for Nondestructive Inspection Methods, provides complete coverage on magnetic particle inspection and all other nondestructive inspection processes discussed in this chapter.

MAGNETIZING EQUIPMENT

STANDARD GENERAL-PURPOSE UNIT

A standard general-purpose unit used at many naval air activities is shown in Figure 7-14. This unit provides direct current for wet continuous or residual magnetization procedures. Either circular or longitudinal magnetization may be used, and it may be powered with rectified alternating current as well as direct current.

The contact heads (1) and (2) provide the electrical terminals for circular magnetization. One head (1) is fixed in position. Its contact plate (3) is mounted on a shaft surrounded by a pressure spring (5), in order that the plate may be moved longitudinally. The plate is maintained in the extended position by the spring until pressure transmitted through the work from the movable head forces it back.

The movable head slides horizontally in logitudinal guides and is motor driven. It is controlled by a switch (7). The spring (5) allows sufficient overrun of the motor driven head to avoid jamming it, and also provides pressure on the ends of the work to insure good electrical contact.

A plunger-operated switch in the fixed head cuts out the forward motion circuit of the movable head motor when the spring has been properly compressed.

In some units the movable head is hand operated, and the contact plate is sometimes arranged for operation by an air ram. Both contact plates (3 and 4) are fitted with various fixtures for supporting the work.

The magnetizing circuit is closed by depressing a pushbutton (6) on the front of the unit. An automatic timer controls the duration of the shot or current flow. A shot of 3/4 to 1 1/4 seconds duration is recommended.

The strength of the magnetizing current may be set manually to the desired value by means of the rheostat (9), or increased to the capacity of the unit by the rheostat short-circuiting switch (15). The current utilized is indicated on the ammeter (8).

Longitudinal magnetization is produced by the coil (10), which moves in the same guide rail as the movable head and is connected in the electrical circuit by means of a switch (11).

The suspension is contained in a sump tank and is agitated and circulated by a pump (14). The suspension is applied to the work through a nozzle (12). The suspension drains from the work through the wood grill into a collecting pan that leads back to the sump. The circulating pump is operated by a pushbutton switch (13).

GENERAL-PURPOSE PORTABLE UNIT

It is often necessary to perform the magnetic particle inspection at locations where standard general-purpose equipment is not available, or to perform an inspection on members of aircraft structures without removing them from the aircraft. This has occurred, particularly on landing gears and engine mounts suspected of having developed cracks in service. Equipment suitable for this purpose, supplying both alternating-current and direct-current magnetization, is available.

A typical example of a portable magnetic inspection unit and common accessories is provided in Figure 7-15.

This unit is only a source of magnetizing and demagnetizing current and does not provide a means of supporting the work or applying the suspension. It operates on 220-440 volt, 50-60 hertz (cycles per second) alternating current and contains a rectifier for producing direct current when required.

The magnetizing current is supplied through the two flexible cables. The cable terminals may be fitted with prods, as shown in the illustration, or with electrical clips. Circular magnetization may be developed by using either the prods or the clips. Longitudinal magnetization is developed by wrapping the cable around the part.

The strength of the magnetizing current is controlled by the 30-point rotary (tap) switch. This switch is used to manually select the amount of magnetizing current required for the job at hand. Output currents up to 3,000 amperes are available on either a.c. or d.c. with normal length output cables. The amount of current available on any tap or switch setting depends upon the resistance in the output circuit. In general, the lower the tap setting the higher the ampere setting that is available with tap number 30 providing the lowest current. During automatic demagnetization, using the DEMAG switch, the rotary switch is motor driven to reduce the output current in steps from any preset contact position to the minimum current obtainable on contact No. 30.

The control cable shown in Figure 7-15 has two pushbuttons marked START and STOP. With line voltage available to the unit and the control cable connected to its receptacle, pressing the start button completes the circuit to the output terminals.

The DEMAG switch located on the front of the cabinet is depressed along with the START switch on the control cable to initiate the automatic demagnetizing cycle.

One prod assembly has a built-in control switch which connects through a cable to the control cable receptacle. When prods are being used, this switch serves the same function as the start button on the control cable. When depressed, the switch directs power to the output terminals.

The red pilot light glows whenever line current is supplied to the unit. The input line switch is located on the right-hand end of the cabinet. The green pilot light is wired in the output circuit and will glow whenever the start button on the control cable or the prod control switch is depressed.

The d-c ammeter indicates the output current when d-c current is being used for magnetization. The a-c ammeter indicates the output current when a-c current is being used for magnetization or demagnetization.

The 110-volt a-c receptacle is provided for convenience in plugging in lamps or other auxiliary equipment that may be required when performing inspections with the unit. Operating and servicing instructions for this unit are provided in detail in NavAir 17-15-16.

PARKER CONTOUR PROBE UNIT

The Parker Contour Probe, illustrated in Figure 7-16, is a portable self-contained unit with flexible pole pieces that permit concentrated magnetic fields to be induced at the area to be inspected, regardless of part size or mass. Its solid state circuitry, contained within the aluminum handle, produces a constant a-c magnetic field or a high intensity pulsed d-c field that is variable from zero to maximum intensity.

Basically, the contour probe is an improvisation of the C-shaped yoke with the addition of movable poles to permit the concentrated fields to be focused and applied at a precise area. The probe is capable of reproducing or duplicating any surface defect indication obtained by the use of large, high-amperage units discussed previously.

A-c magnetization is induced in the part being inspected as a skin or surface field and does not penetrate the cross section of the material. It is used when only surface indications are required. It is most desirable for inspecting large masses and soft materials such as cast iron. With a.c., the polarity reversal at the 60-hertz rate produces a profound surge peak that is reflected in the magnetic field produced by the coil. Byproducts of a-c magnetization are the formation of eddy currents that tend to guide or direct the magnetic field in a narrow pattern between the poles and a vibratory action at the workpiece that adds mobility to the inspection particles to form a large and sharper buildup at the defect. A.c. is used for the demagnetization process.

Pulsed d-c magnetization penetrates the entire cross section of the workpiece and tends to spread out on each side of the line between the poles, thus dispersing the field energy over a greater area. To offset the dissipation of the energy, the magnetic field strength in the maximum d-c position is almost double that of the a-c mode. The d-c mode can be used in the residual method of inspection of small parts. When using a.c. or d.c. on small parts, an excess amount of field will completely saturate the part and cause a masking effect that blurs or obliterates defect indications. Always use the lowest current setting that will produce sharp and distinct indications with maximum sensitivity.

The probe pole pieces are adjustable to a variety of configurations. They can be extended to a maximum of 18 inches; however, it is recommended that when possible they be used with a space of approximately 5 to 6 inches inside diameter. The closer spacing provides a higher density field over a small area.

Operation of the contour probe is simple. With the probe set in either the a-c or the maximum d-c position, place the pole pieces on the work with the suspected defect at right angles to the poles. Push the test switch and dust or float the inspection powder over the area being inspected. Release the test switch immediately after application of the inspection powder. Read defect indications revealed by the accumulation of inspection powder over defects. Turn the probe 90 degrees and repeat the procedure so that defects oriented opposite to the first indication may be revealed. Figure 7-16 illustrates the contour probe being used to inspect a jet engine tailpipe weld and the resulting indications.

The probe should be operated on 105-125 volts a-c, 60-hertz, single-phase power. The duty cycle for the test switch should not exceed 2 minutes ON, 2 minutes OFF. Heating of the coil cover indicates excessive ON time. The selector switch for a.c./d.c. should not be changed with the test switch depressed.

ACCESSORIES AND FIXTURES

Clamps and Prods

In testing large items with flat surfaces such as engine section rings, it is desirable to use clamping devices to facilitate application of the magnetizing current. On parts where it is impractical to use clamps, prods similar to those illustrated in Figure 7-6 are used.

Prods may be used with the standard general-purpose unit and the portable unit. The part or assembly being tested may be suspended above

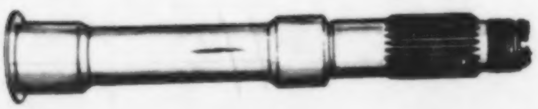

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Figure 7-9.—Fatigue crack in crankshaft.

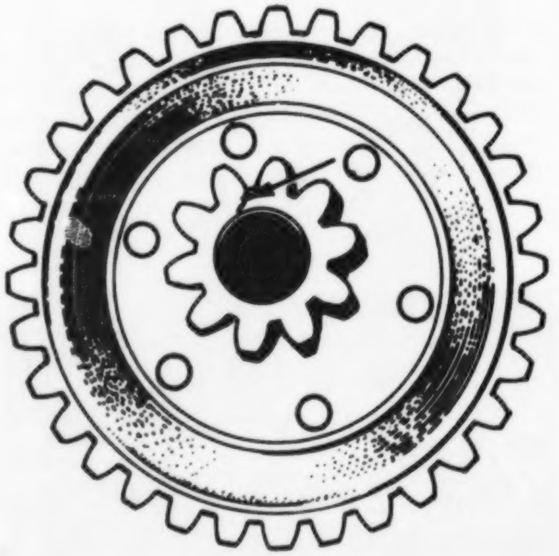

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Figure 7-10.—Fatigue crack in a gear.

the standard unit and the wet suspension indicating medium hosed onto the area with the excess suspension draining into the tank. The dry indicating medium may also be used.

In using the prods, they should be held firmly against the surface being tested. This will prevent or minimize the tendency for burning at the contact points. For applications where prod magnetization is acceptable, slight burning is normally not objectionable.

Contact Blocks

When it is desired to use cable with the standard general-purpose unit as a source of power, a contact block is useful. This consists of a wooden block fitted at each end with copper plates spaced to receive the terminals of the cable.

When the contact block is placed between the heads of a standard unit, the regular controls and timing switches of the unit can be used to regulate the magnetizing current. This provides a convenient way of connecting the cable to a power source and eliminates the necessity for bolted connections. Recommended magnetizing currents, for specific applications including the recommended current path and ampere value, are given in NavAir 01-1A-16.

Propeller Blade Fixtures

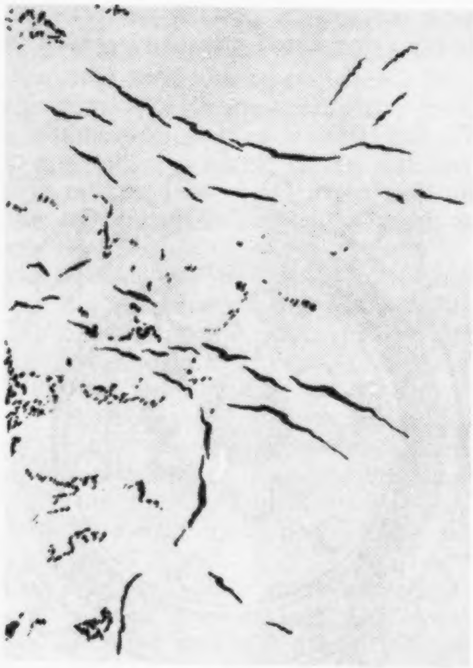
When magnetizing current is passed through a propeller blade for circular magnetization, it is possible to burn the blade tip. This possibility can be avoided by the use of a hinged clamp attached to the movable head of the inspection unit, as shown in Figure 7-17.

The clamp is lined with copper braid, which provides a good electrical contact by conforming to the curvature of the propeller blade faces. This fixture arrangement eliminates high current intensities at the thin edge of the blade tip, which may cause burning at the point. The butt end of the blade is supported by a plug mounted on the opposite head.

MAGNETIZING MATERIALS

LIQUID VEHICLE FOR WET SUSPENSION

The liquid vehicle in the wet procedure performs the basic function of providing mobil-



AM.492
Figure 7-11.—Heat-treat cracks on cylinder barrel wall.

AM.493
Figure 7-12.—Shrink crack in welded joint.

ity for the suspended magnetic particles. The liquid for the oil suspended method should be a light oil such as kerosene or drycleaning solvent. Water with a suitable inhibitor and wetting agent may be used as a liquid vehicle. Most magnetic materials for suspension in water are supplied with water conditioners which have some rust-inhibiting characteristics and also increase the wetting action of the bath. If materials without water conditioners are used, it will be necessary to add them to the bath. The type and amount of water conditioner used should be in accordance with the manufacturer's recommendations. Too much conditioner will make the bath foam.

INDICATING MEDIUMS

The various types of indicating mediums available for magnetic particle inspection may be divided into two general types–wet process and dry process materials. The basic requirement for any indicating medium is that it produce acceptable indications of discontinuities in parts.

The contrast provided by a particular indicating medium on the background or part surface is particularly important. The indicating medium is available in black, red, and fluorescent for the wet process; and black, red, and gray for the dry process.

For acceptable operation, the indicating medium must be of high permeability and low retentivity. High permeability insures that a minimum of magnetic energy will be required to attract the material to flux leakage caused by discontinuities. Low retentivity insures that the mobility of the magnetic particles will not be hindered; that is, by the particles themselves becoming magnetized and attracting one another.

The magnetic substance for the wet process is usually supplied in paste form. The red paste improves visibility on dark surfaces. Fluorescent paste particles must be viewed under black light. The big advantage of fluorescent paste is the greatly increased visibility over pastes viewed under normal light.

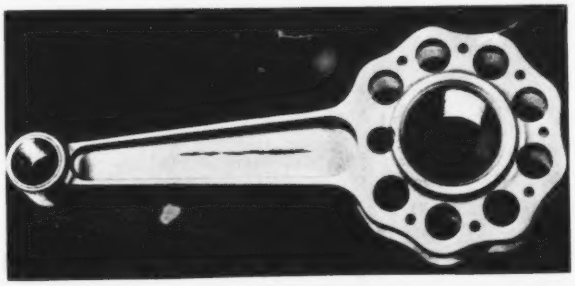
When the suspension becomes discolored or otherwise contaminated to the extent that the formation of magnetic particle patterns is interfered with, the unit should be drained, cleaned, and refilled with clean suspension. When new suspensions are prepared, it is important that the correct amount of paste is used. Oil based baths should be completely replaced at least every 2 months. Water suspended baths should be replaced at least every 30 days.

Mixing the Bath (Oil Suspended Wet Method)

The proper procedure in preparing a suspension is to weigh or measure the paste into a clean container. When using black or red paste, measure out 1.50 ounces per gallon of oil. If the fluorescent paste is used, measure out 0.25 ounce per gallon of oil. If a dry concentrate is used, measure 0.20 ounce per gallon of oil. The dry particles may be poured directly into the tank, preferably over the sump for proper dispersing. The paste type particles, being placed in a container, are diluted with small quantities of the liquid vehicle and mixed until they become a uniform watery mixture that can be poured into the tank. With the pump motor on, the mixture is poured over the sump area and the motor is run several minutes.

Mixing the Bath (Water Suspended Wet Method)

Magnetic particle baths using water as a vehicle require close control. They are recommended for use in activities performing magnetic particle inspections on a full time basis. The particles may come in a paste or as a powder. They should always be used in accordance with

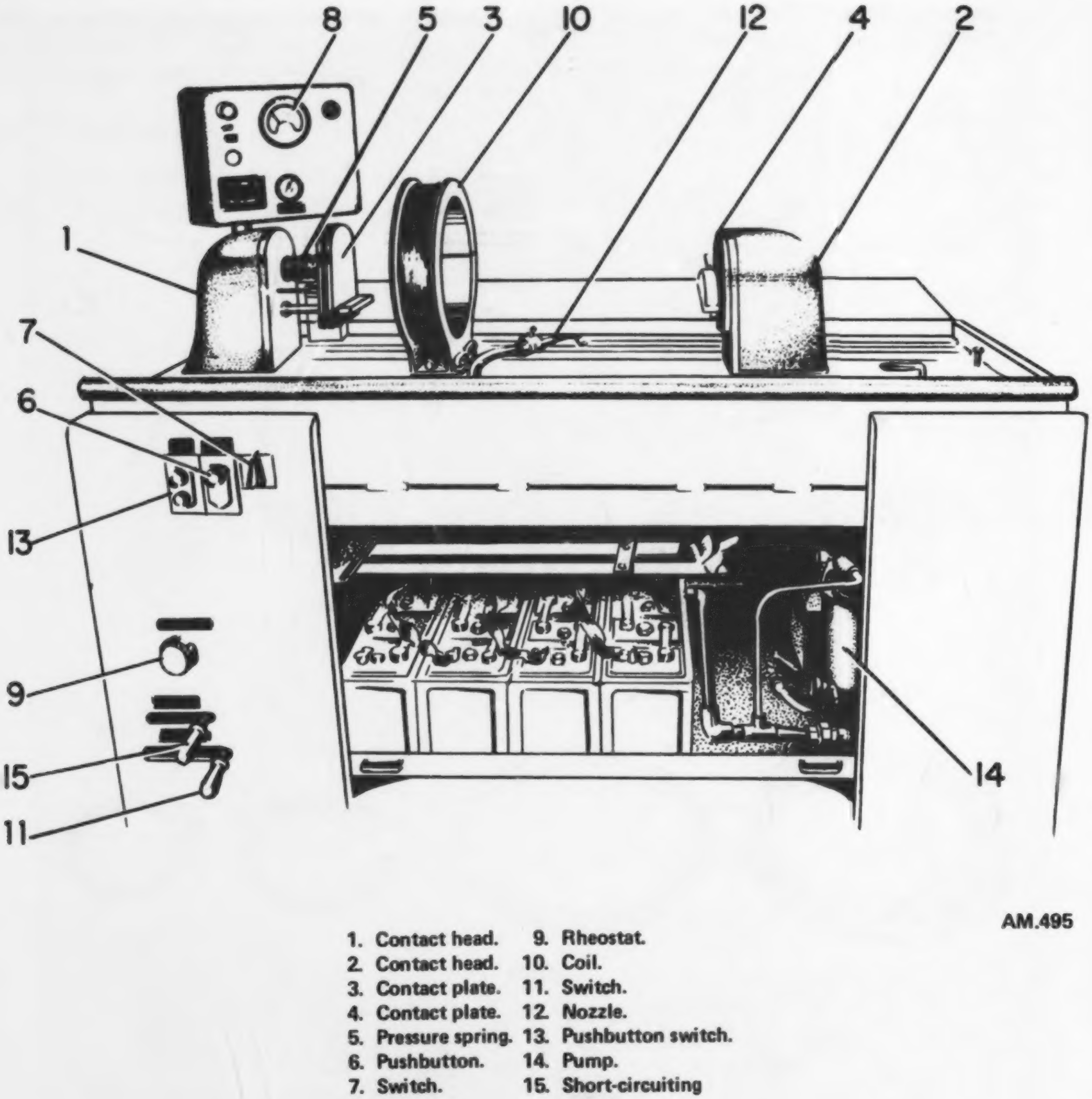


AM.494

Figure 7-13.–Seam in master rod.

Table 7-1.—Nonrelevant magnetic particle indications

Type of nonrelevancy	Indication characteristics
Structural.	Fairly wide, lacking character and clarity. Usually show relationship to abrupt structural changes in section such as keyways, drilled holes near the surface or bandings. Can mask significant indications, particularly if field strength is too high. (To eliminate nonrelevant indications where significant discontinuities are suspected, the field strength should be lowered or holes should be plugged with a ferromagnetic material.)
Material variation.	Confusing and unrelated to discontinuities. Caused by strong local poles or zero fields in the material under test, such as in cold worked areas.
Dissimilar metal contact.	Occur at points where defects are likely to be found. Cannot be eliminated by reduction of field strength. Difficult to distinguish from significant indications on dissimilar metals, especially when welded. (Several procedures are recommended for the inspection of such parts: magnetic particle test for ferromagnetic areas; possibly fluorescent penetrant test for nonmagnetic parts and junctions; and magnification, or possibly etching, for abrupt changes of section between two weld beads.)
Magnetic writing.	Usually vague and without character but can be sharp and clear and positioned to simulate actual discontinuities. Disappear on demagnetization and reinspection. (Parts should be kept from striking each other or other ferromagnetic materials to prevent local surface polarities and flux leakages from producing magnetic writing during inspection.)
Strains.	Reasonably sharp and distinct when caused by local cold working from blows and scratches. Specific patterns indicate obliterated stamp markings. Are produced by internal strains because of differences in the magnetic properties of strained and unstrained sections. Reappear after demagnetization and remagnetization. Infrequently encountered. Are sometimes confused with indications of surface defects and subsurface inclusions. (Differences can be discovered when some of the metal of the area is removed: indications decrease with nonrelevant local cold-working, remain unchanged or increase with subsurface discontinuity.)
Faulty operation.	Frequently resemble indications of discontinuities when trapped by grease or other foreign material left on part surface, but do not reappear after part is thoroughly cleaned and reinspected. Accumulate at low points during draining of cylindrical parts with long axis horizontal, unless removed by rinsing. Caused by scale on surface of part. (Scale forced into the surface of the metal during forging may produce significant indications difficult to identify; removal of small portion of the metal permits positive or negative identification.)
Scratches.	May have characteristics similar to those of cracks, such as orientation transverse to grain flow; distinguished by lack of buildup.

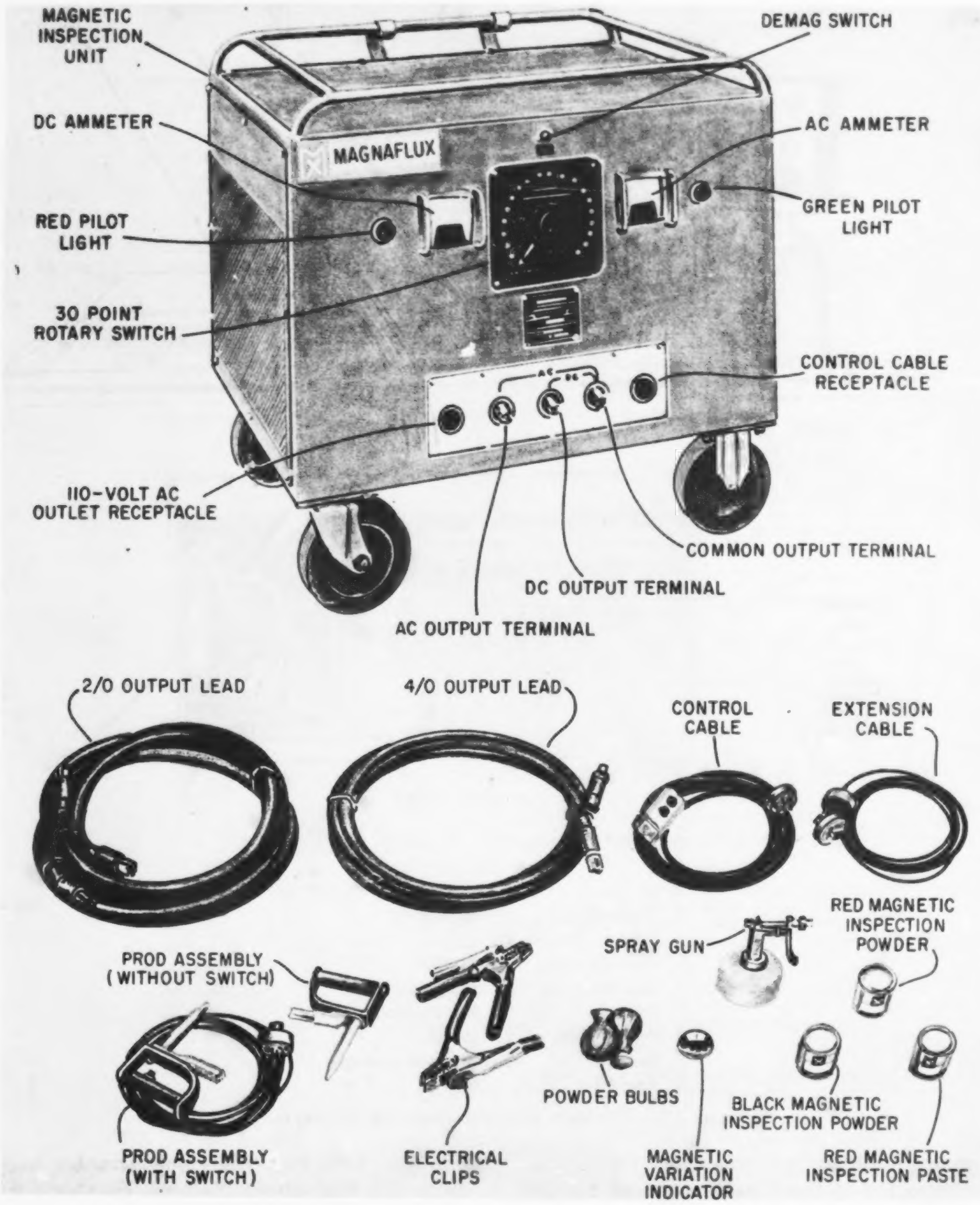


AM.495

1. Contact head.
2. Contact head.
3. Contact plate.
4. Contact plate.
5. Pressure spring.
6. Pushbutton.
7. Switch.
8. Ammeter.
9. Rheostat.
10. Coil.
11. Switch.
12. Nozzle.
13. Pushbutton switch.
14. Pump.
15. Short-circuiting switch.

Figure 7-14.—Standard general-purpose magnetizing unit.

the manufacturers' recommended procedures. When using red or black paste, measure out 2.4 to 4.4 ounces per gallon of water. If the fluorescent paste is used, measure out 0.16 to 0.20 ounces per gallon. Add a little water from the tank to the paste in the container and mix until a uniform, thin mixture is obtained. Pour into the tank over the sump area for proper dispersing throughout the tank. Powdered form fluorescent particles may be added to the water suspension material by weighing out the proper amount of powder, following the manufacturer's recommendations, and pouring the powder directly into the tank over the sump area. In every


MAGNETIC INSPECTION UNIT
DEMAG SWITCH
DC AMMETER
AC AMMETER
MAGNAFLUX
RED PILOT LIGHT
GREEN PILOT LIGHT
30 POINT ROTARY SWITCH
CONTROL CABLE RECEPTACLE
110-VOLT AC OUTLET RECEPTACLE
COMMON OUTPUT TERMINAL
DC OUTPUT TERMINAL
AC OUTPUT TERMINAL
2/0 OUTPUT LEAD
4/0 OUTPUT LEAD
CONTROL CABLE
EXTENSION CABLE
RED MAGNETIC INSPECTION POWDER
SPRAY GUN
PROD ASSEMBLY (WITHOUT SWITCH)
POWDER BULBS
BLACK MAGNETIC INSPECTION POWDER
PROD ASSEMBLY (WITH SWITCH)
ELECTRICAL CLIPS
MAGNETIC VARIATION INDICATOR
RED MAGNETIC INSPECTION PASTE

AM.917

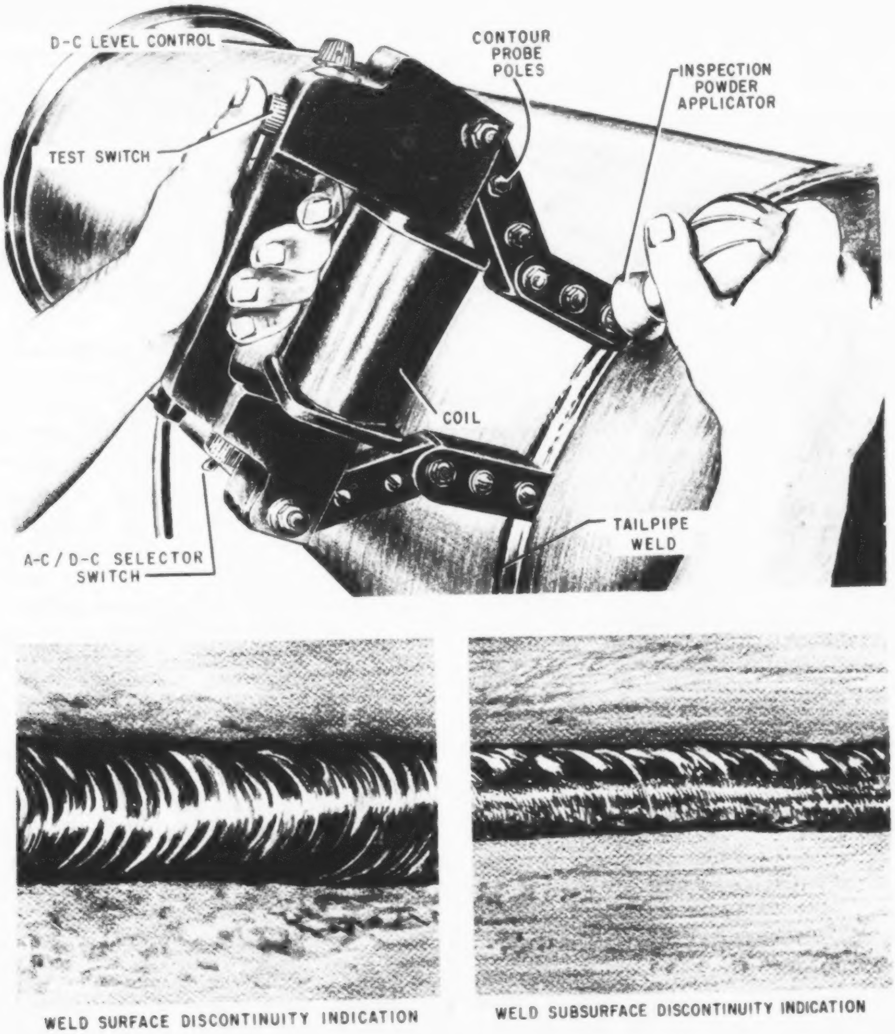
Figure 7-15.—Portable magnetic inspection unit and accessories.

case of adding material to the tank, the pump motor should be run several minutes to thoroughly agitate the mixture.

Bath Strength

The bath strength of oil suspendible baths should be checked each day. The bath strength and wetting ability of water suspendible baths should be checked before each work period and every 4 hours of operation.

The bath strength is checked by using a centrifuge tube (View A, Fig. 7-18) filled with properly agitated bath mixture. The centrifuge is allowed to set approximately 30 minutes, and the amount of particles settling to the bottom

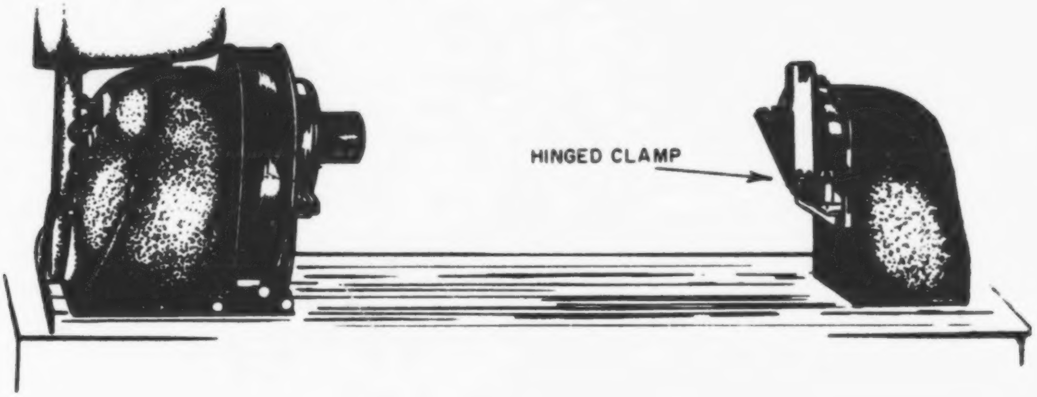

D-C LEVEL CONTROL
CONTOUR PROBE POLES
INSPECTION POWDER APPLICATOR
TEST SWITCH
COIL
TAILPIPE WELD
A-C / D-C SELECTOR SWITCH

WELD SURFACE DISCONTINUITY INDICATION

WELD SUBSURFACE DISCONTINUITY INDICATION

AM.918

Figure 7-16.—Parker Contour Probe being used to inspect tailpipe welds.



AM.498

Figure 7-17.—Propeller blade fixture.

indicates the bath strength. For black or red paste, the reading should be from 1.70 to 2.40 cc; for fluorescent paste, from 0.10 to 0.50 cc; and for dry concentrate, 0.35 to 0.40 cc (View B, Fig. 7-18).

The wetting ability of water based baths should be checked after the strength test has been completed. The bath from the hose should be flowed over a test part having a finely ground flat surface. If the bath does not thoroughly and completely cover the ground surface but tends to run back from the edges of it, an additional amount of water conditioner should be added until complete wetting of the surface is obtained. Water conditioner should be added in small quantities and the wetting ability tested because too much conditioner causes excess foaming of the bath.

Application of Indicating Mediums

The wet type materials, after being properly agitated, may be poured or hosed onto the surface.

The dry type particles should be floated to the surface and not forcibly thrown against it. Do not pour the particles on or roll the magnetized part in particles as the particles will not be as free as necessary to be attracted to the leakage field and poor indications will result. Normally, field units use small rubber spray bulbs or shakers. These devices allow for gentle application of the indicating particles.

DEMAGNETIZATION

NECESSITY FOR DEMAGNETIZATION

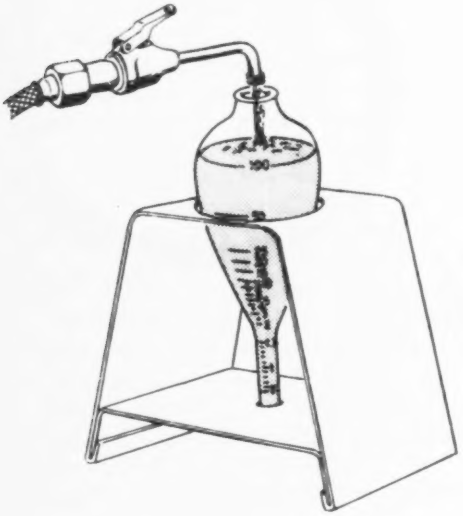
In aircraft parts, the permanent magnetism remaining after inspection must be removed by a demagnetization operation if the part is to be returned to service. Parts of operating mechanisms must be demagnetized to prevent magnetized parts from attracting filings, grindings or chips inadvertently left in the system, or steel particles resulting from operational wear.

An accumulation of such particles on a magnetized part may cause scoring of bearings or other working parts. Parts of the airframe must be demagnetized so that they will not affect instruments.

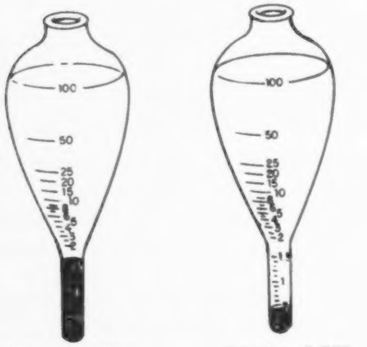
Demagnetization of a part is not required if the part is to be heat treated and brought up to a temperature of 1700° F or higher, will become magnetized during further handling, or is to be magnetized later in another direction to the same or higher level than it was originally magnetized.

BASIC THEORY

Demagnetization may be accomplished in a number of different ways. Possibly the most convenient procedure for aircraft parts involves subjecting the part to a magnetizing force that is continually reversing in direction and, at the same time, gradually decreasing in strength. As the decreasing magnetizing force is applied first in one direction and then the other, the magnetization of the part also decreases.



FILLING CENTRIFUGE TUBE
(A)



1.7CC to 2.4CC
BLACK OR
RED PASTE

0.1CC to 0.5CC
FLUORESCENT
PASTE

INDICATION OF PROPER AMOUNT OF SETTLED PARTICLES
(B)

AM.491

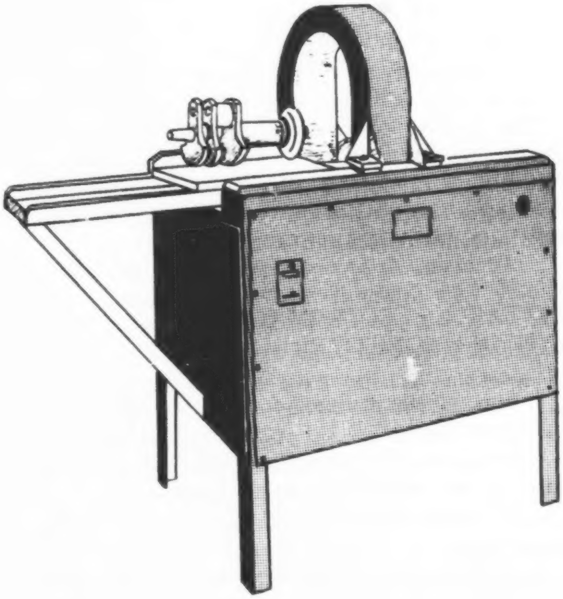
Figure 7-18.–Checking bath strength using centrifuge tube.

STANDARD DEMAGNETIZING PRACTICE

The simplest procedure for developing a reversing and gradually decreasing magnetizing force in a part involves the use of a coil energized by alternating current. As the part is moved away from the alternating field of the coil, the magnetism in the part gradually decreases.

This principle is utilized in the demagnetizer shown in Figure 7-19. In demagnetizers of this type, the strength of the demagnetizing field decreases toward the center of the coil. A demagnetizer as near the size of the work as practicable should be used; and for maximum effectiveness, small parts should also be held as close to the inner wall of the coil as possible.

Parts that do not readily lose their magnetism should be passed slowly in and out of the demagnetizer several times, and at the same time tumbled or rotated in various directions. Allowing a part to remain in the demagnetizer with



AM.499

Figure 7-19.–Narrow coil demagnetizer.

the current on accomplishes very little practical demagnetization.

The effective operation in the demagnetizing procedure is that of slowly moving the part out of the coil and away from the magnetizing field strength. As the part is withdrawn, it should be kept directly opposite the opening until it is 1 or 2 feet from the demagnetizer.

The demagnetizing current should never be cut off until the part is 4 or 5 feet from the opening, as this will usually result in remagnetization of the part.

DEMAGNETIZING EQUIPMENT

NARROW COIL SOLENOID

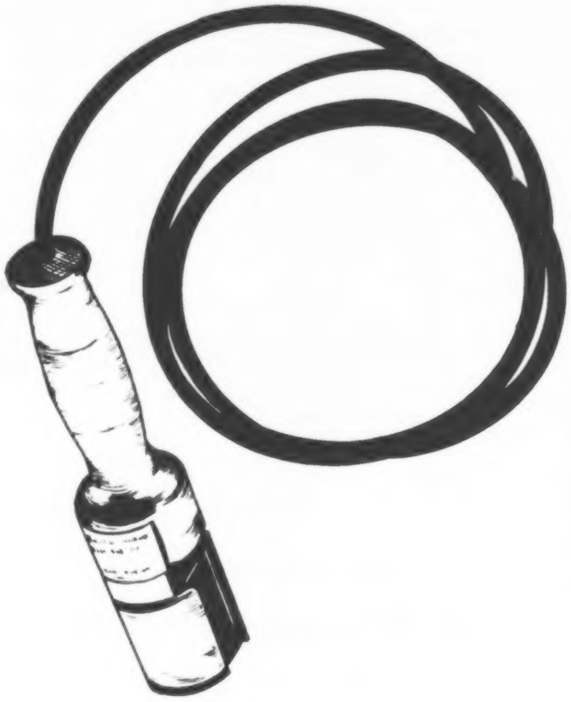
The most widely used type of demagnetizer consists of a solenoid excited by alternating current. An example of this type demagnetizer is shown in Figure 7-19. The windings consist of flat copper strip compactly wound to shorten the length of the demagnetizer. These demagnetizers are normally supplied in different sized openings to efficiently handle various sized parts. A sliding carrier may be incorporated for convenience in demagnetizing heavy parts.

The narrow coil demagnetizer heats quickly and is not designed for very long periods of continuous operation. The manufacturer's instructions should always be consulted for the intermittent operation of these units.

PORTABLE ELECTROMAGNET TYPE DEMAGNETIZER

A portable electromagnet type demagnitizer is shown in Figure 7-20. It consists of a flat slab electromagnet, wound in the long direction. The faces of the exposed pole ends are rounded to permit access into localized areas, such as holes or corners.

The demagnetizer produces an external alternating field when excited by alternating current. When it is slowly moved away from the part, it demagnetizes the adjacent area in the usual manner.



AM.500

Figure 7-20.—Hand type demagnetizer.

This tool is convenient for use on localized areas difficult to demagnetize by the standard procedure. It requires a power source of about 3 amperes and 100 volts at 60 hertz, and may thus be plugged into most lighting circuits.

PARKER CONTOUR PROBE DEMAGNETIZATION FEATURE

Demagnetization with the Parker Contour Probe is accomplished using alternating current. Small pieces which have been residually magnetized by either the a-c or the d-c method are passed through the area between the poles and withdrawn to a distance of 2 feet before the test switch is released. On larger pieces, place the probe in the same position used for magnetizing the part, turn on the probe and lift from the work to a distance of 2 feet before releasing the test switch.

INSPECTION RECORDS AND REPORTS

The results of magnetic particle inspections can be recorded for future reference by a variety of methods. If the part is being retained for further viewing or being shipped to a higher level maintenance activity, it may be desirable to fix the indication in place on the part. This may be accomplished using a lacquer overspray or applying transparent tape over the indications. Other methods include simple sketches, photographs, and tape transfer of indications onto stiff white paper.

Reports of unsatisfactory or defective materials revealed by magnetic particle inspection should be made on the Unsatisfactory Material/Condition Report (UR), OpNav Form 4790/47. Such reports should contain a complete identification of the part, a visual record of the results with a supplemental written description, a complete evaluation of the indication, and the procedure used to magnetize the part and apply the indicating medium, including the current strength for circular magnetization or the ampere turns for longitudinal magnetization.

RADIOGRAPHIC INSPECTION

Radiographic inspection procedures operate on the same principle doctors employ in X-raying the human body. Radiation is projected through the item to be tested and the result is captured on film, which is then developed much like a photographer processes film from his camera. This inspection medium, in a portable unit as shown in Figure 7-21, provides a fast and reliable means for checking integrity of aircraft structures.

The prime purpose of portable X-ray is to locate defects or flaws in aircraft structures with little or no disassembly. This is in marked contrast to other types of nondestructive testing which usually require removal, disassembly, and stripping of paint from the suspected part before inspection can be accomplished. Figure 7-22 is a photograph of a portable X-ray tubehead unit being positioned for X-raying the upper flange of a box beam assembly. The control panel (not shown) is positioned a safe distance away.

X-RAY PROCESS

There are three major steps in the X-ray process. The steps are:

1. Exposure to radiation, including preparation.
2. Processing of the film.
3. Interpretation of the radiograph.

Figure 7-23 is a diagram of radiographic exposure showing the elements of the system. Radiation passes through the object and produces an invisible or latent image in the film. When processed, the film becomes a radiograph or shadow picture of the object. Since more radiation passes through the object where the section is thin or where there is a space or void, the corresponding area on the film is darker. The radiograph is read or interpreted by comparing it with the known nature of the object.

Radiographic Interpretation

The usefulness of the information obtained from the radiographic process depends upon the intelligent interpretation of the derived image. To successfully interpret the radiograph, the radiographer must have a working knowledge of the component or material and be able to relate the images to the conditions likely to occur. This background is not necessary to produce good radiographs; however, it does assist in the selection of the exposure angle and in determining the correct thickness of the material.

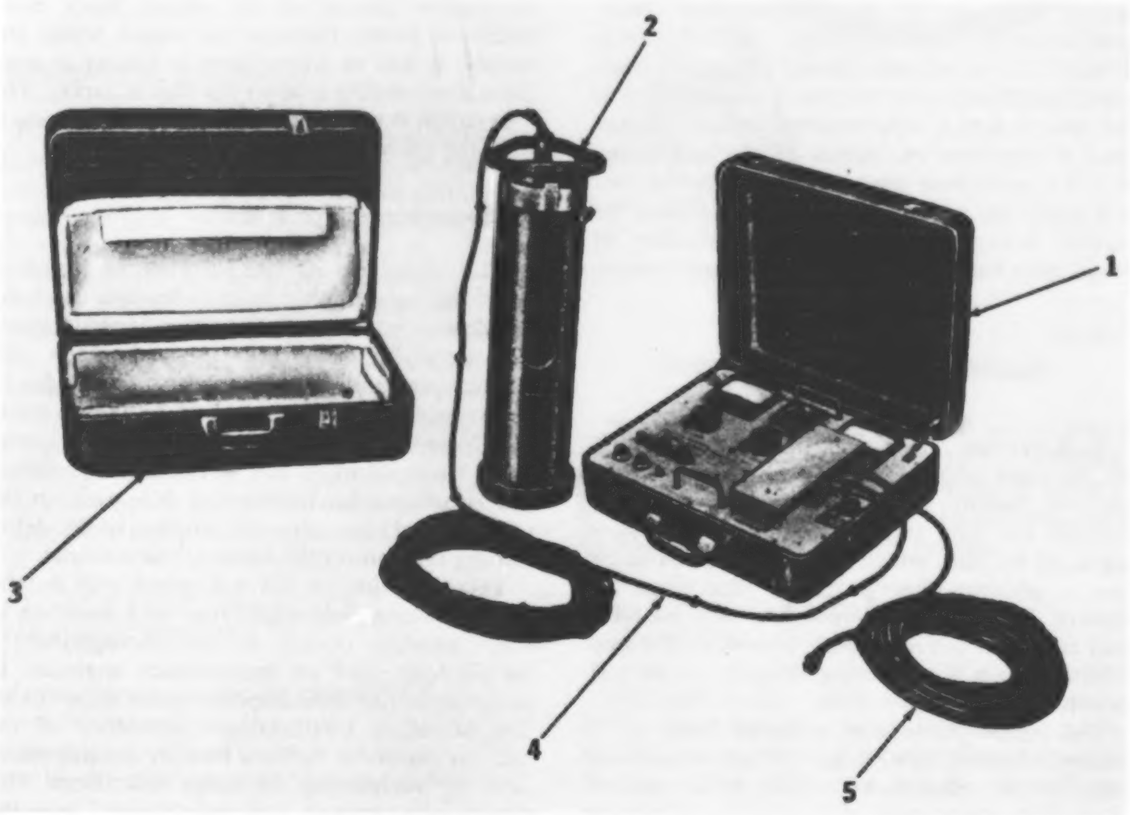
Interpretation of the radiograph may require the knowledge and experience of a team which may possibly consist of the radiographer, a metallurgist, and an aeronautical engineer. In such cases, the radiographer would request that the Materials Engineering Laboratory of the nearest Naval Air Rework Facility provide assistance in interpreting the image indications. This teamwork between the radiographer and the Rework Facility should result in an accurate evaluation of the indications to determine the proper disposition of the component.

Radiographic interpretation also requires a knowledge of the absorption characteristics of the material and the radiation used, the contrast and detail features of the film as well as the geometrical relationship of the radiation source, film, and the part being radiographed. A visual inspection of the material should precede X-ray interpretation since surface conditions show clearly on the film, and these conditions should not be misread as existing internal conditions.

RADIATION HAZARD

Radiation from X-ray units and radioisotope sources is destructive to living tissue. It is universally recognized that in the use of such equipment, adequate protection must be provided. Personnel must keep outside the primary X-ray beam at all times.

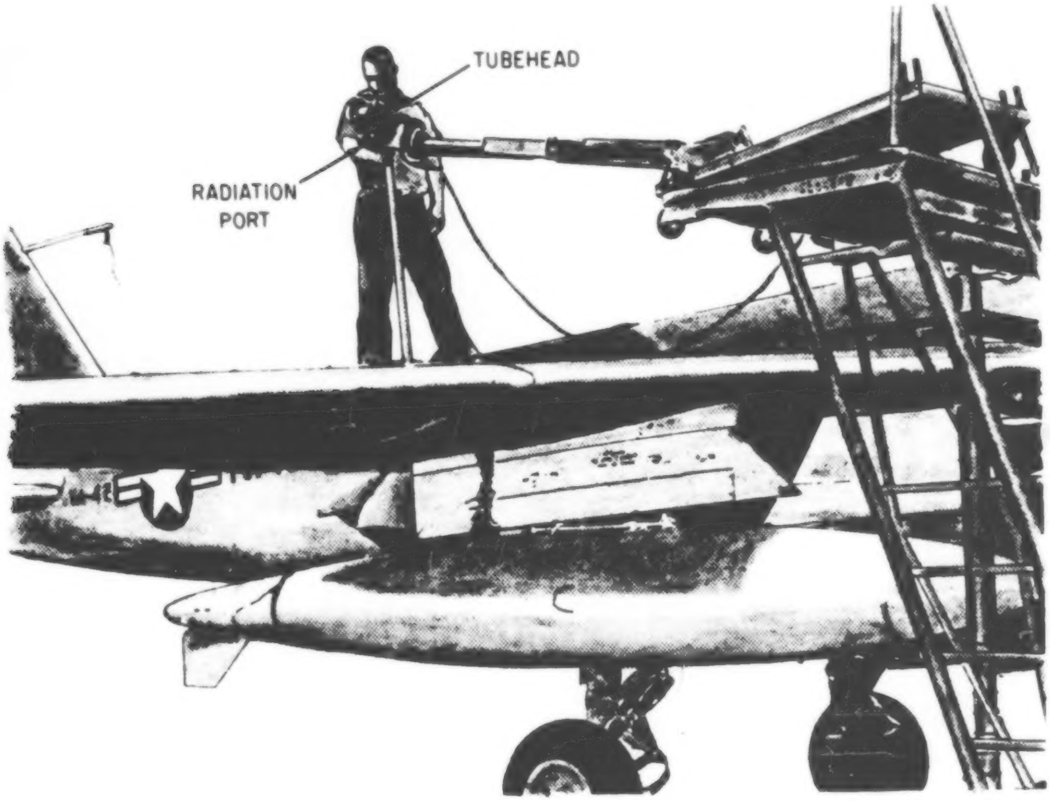
Radiation produces changes in all matter that it passes through. This is also true of living tissue. When the radiation strikes the molecules of the body, the effect may be no more than to dislodge a few electrons; but an excess of these changes could cause irreparable harm. When a complex organism is exposed to radiation, the degree of damage, if any, depends on which of



AM.488

1. Control panel.
2. Tubehead unit.
3. Tubehead case.
4. Control cable.
5. Power cable.

Figure 7-21.—Portable X-ray unit.



AM.496

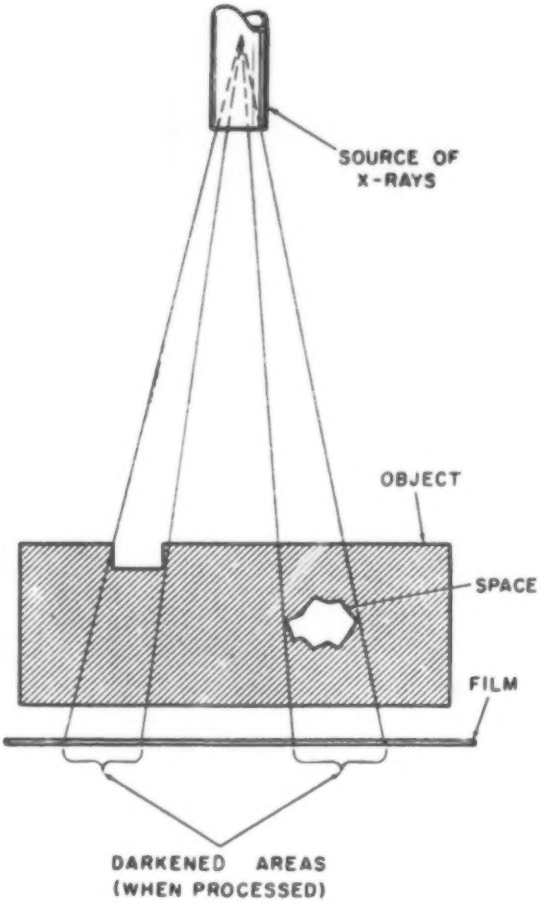
Figure 7-22.–Tubehead unit positioned for X-raying.

its body cells have been changed. The more vital parts are in the center of the body; therefore, the more penetrating radiation is likely to be the most harmful in these areas. The skin usually absorbs most of the radiation, and therefore, reacts earliest to radiation.

If the whole body is exposed to a very large dose of radiation, it could result in death. In general, the type and severity of the pathological effects of radiation depend on the amount of radiation received at one time and the percentage of the total body exposed. The smaller doses of radiation may cause blood and intestinal disorders in a short period of time. The more delayed effects are leukemia and cancer. Skin damage and loss of hair are also possible results of exposure to radiation.

Safety Precautions

Prior to commencing any radiographic inspection, the radiographers must register with the local Radiological Health Officer and obtain film badges from the Medical Department. All applicable regulations must be complied with. All radiographic operations must be performed within a RESTRICTED roped-off area radiac monitored to insure that personnel are not subjected to excessive radiation. The roped-off area must be identified with Atomic Energy Commission (AEC) warning signs. No personnel other than the authorized radiographer and his assistant shall be allowed within this roped-off area during radiographic operations. If desired, a second person, who is not necessarily a qualified



AM.502

Figure 7-23.—Radiographic exposure diagram.

radiographer, may be assigned to assist the radiographer. In any event, this assistant must be thoroughly instructed in the hazards and safety regulations concerning radiography and be registered with the Radiological Health Officer. The (foregoing) precautions apply to shore base operations only.

Shipboard safety precautions are similar but are modified to conform to conditions as they exist aboard ship.

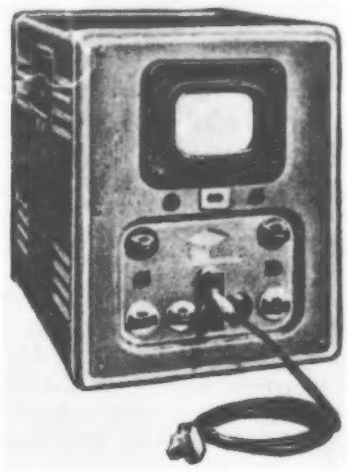
ULTRASONIC INSPECTION

Ultrasonic inspection is accomplished by an instrument that electronically generates ultrasonic vibrations that penetrate the part to be tested, revealing flaws and discontinuities. Any flaws or discontinuities will reflect the vibrations back to the instrument, which measures the elapsed time between the initial pulse and the return of all reflections, and indicates such time elapse on a cathode ray tube. One of the instruments used for this type of inspection is referred to as a Reflectoscope. The basic element in this instrument is a transducer for conversion of electrical energy to sound energy, and vice versa. Figure 7-24 illustrates a portable Reflectoscope.

PRINCIPLE OF OPERATION

The Reflectoscope operates as follows:

1. An electrical pulse is generated in the Reflectoscope.
2. This electrical pulse is transformed into mechanical vibrations by the search unit crystal.



AM.503

Figure 7-24.—Portable Reflectoscope.

3. The pulse of high frequency vibrations is projected into the material.
4. A portion of the pulse strikes the defect and is reflected back toward the entrant surface and a portion continues through to the opposite boundary.
5. The beam of vibrations is reflected from the back surface toward the entrant surface.
6. Those returning pulses reach the crystal where they are transformed back into electrical pulses.
7. The returning energy is amplified electronically by the Reflectoscope.
8. These amplified signals are displayed on the cathode ray tube screen as vertical pips. The pips are spaced along the horizontal sweep line from left to right according to their time of arrival. The spacing is in proportion to the distance between the points in the material they represent.

INSPECTION METHODS

All Reflectoscope inspections are accomplished by direct contact of the search unit with the material being inspected or by the immersion of both the search unit and the material in water or oil, with the search unit a short distance from the material. A quartz crystal in the search unit transforms electrical pulses into mechanical vibrations and then back into electrical pulses. There are four different kinds of search units available, and the one selected depends upon the nature of the test as well as the material being tested.

Straight Beam

This method is used to locate defects by projecting a beam perpendicular to the test surface. The crystal in the unit has one face that is exposed so that it will contact the work.

Angle Beam

This method is used to locate defects by introducing a beam of vibrations at an angle to the surface of the test material. In this manner, discontinuities are located which, due to their orientation, cannot be detected by the straight-beam technique. This angle is determined by placing a wedge between the crystal and the sample. Plastic and resin are two of the various materials from which wedges are fabricated. The wedges are finished to different degrees, depending upon the desired angle.

Surface Wave

This method projects a beam of vibrations which travel along the surface and just below the surface of the material. These vibrations travel over irregular shaped surfaces.

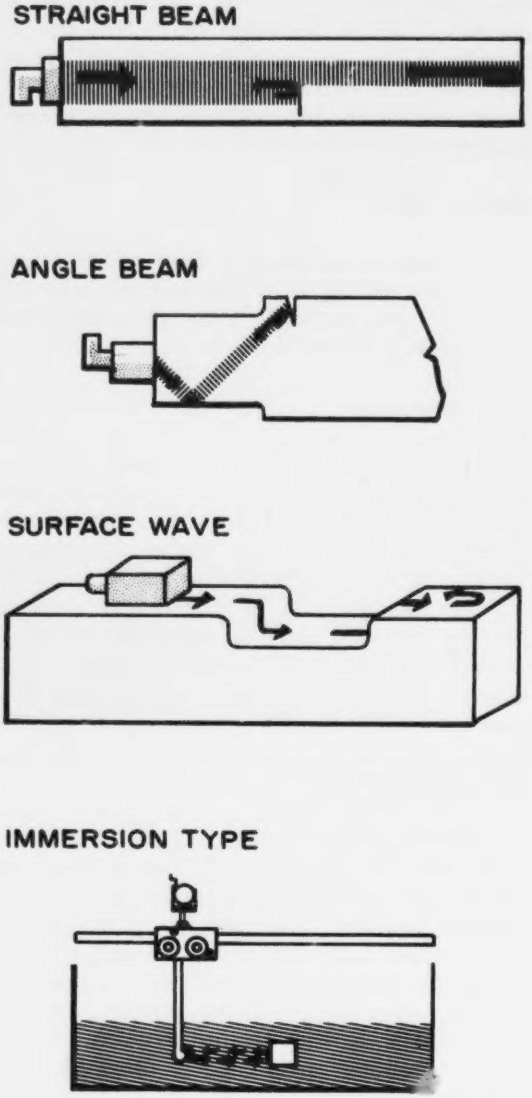
Immersion Type

The immersion type method is used to inspect materials while immersed in a suitable liquid such as water or oil. This method proves more satisfactory than contact testing for irregular shaped surfaces. Immersion inspection also permits use of a wider range of testing frequencies. Straight or angle beam techniques are used by varying the angle of the search unit head in relation to the test surface. Figure 7-25 illustrates the four different methods of inspection.

APPLICATION

Ultrasonic inspection is used for raw material inspection to detect flaws before time and money are spent on the material. It is used for finished product inspection to locate defects prior to final assembly, thus insuring the quality and safety designed into the finished product.

The application of this method to preventive maintenance is the greatest concern for the AMS. Scheduled maintenance, using the portable Reflectoscope for on-the-spot, nondestructive testing of an aircraft landing gear and other components saves dollars in assuring equipment reliability. Costly unpredictable failures are prevented. Throughout the scheduled maintenance program, this type of inspection can facilitate scheduled parts replacement, or planned obsolescence of components can be accomplished with minimum DOWN time and maximum equipment protection. Figure 7-26 illustrates the inspection of an aircraft landing gear.

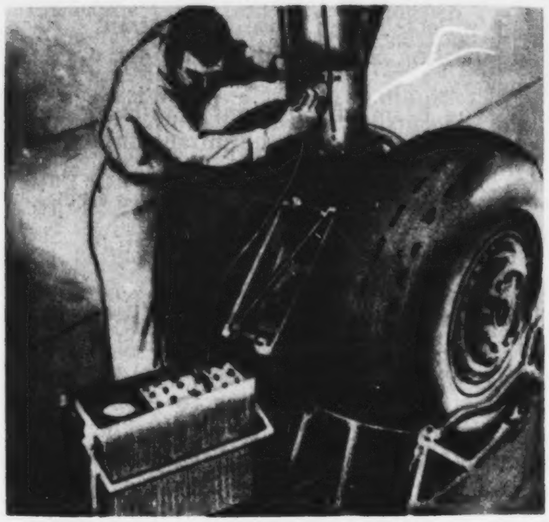


AM.504

Figure 7-25.—Inspection methods.

EDDY CURRENT INSPECTION

Eddy current inspection is the process of using electric current, induced by the influence of a magnetic field, to reveal surface or near surface discontinuities. The electric currents are called eddy currents because they follow closed circular paths or eddies. The induced flow of electrons (eddy current) produces a secondary field of sufficient strength to oppose the primary field, which has been produced by placing the eddy current probe on or close to the material being inspected. Figure 7-27 illustrates eddy currents being produced in a piece of metal. Figure 7-28 shows how these currents are affected by the presence of a discontinuity.



AM.505

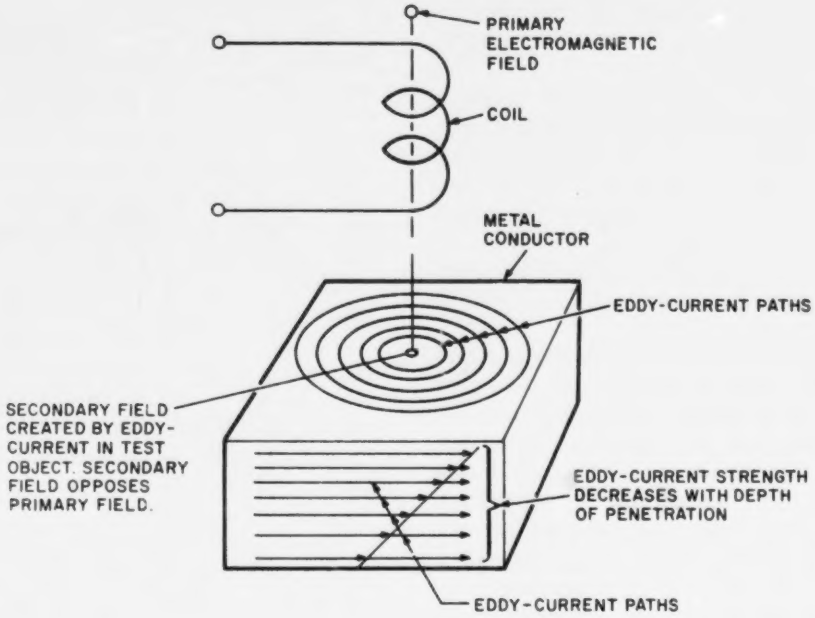
Figure 7-26.—Inspection of an aircraft landing gear.

The degree or amount these currents are affected by a discontinuity causes an upset in the balance between the primary and secondary field and is registered as an up or down scale deflection on the readout device.

APPLICATION

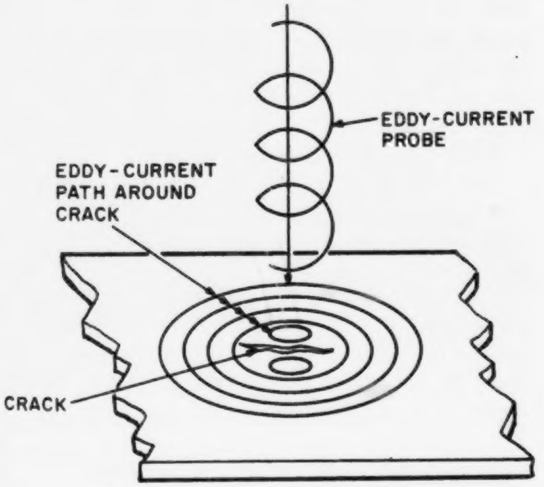
Eddy current instruments were developed primarily for locating cracks around spark plug ports in aircraft cylinders; however, they have since proved to have many applications in aircraft production and maintenance.

Various types of eddy current instruments are capable of supplying the following information concerning parts undergoing tests:


PRIMARY ELECTROMAGNETIC FIELD
COIL
METAL CONDUCTOR
EDDY-CURRENT PATHS
SECONDARY FIELD CREATED BY EDDY-CURRENT IN TEST OBJECT. SECONDARY FIELD OPPOSES PRIMARY FIELD.
EDDY-CURRENT STRENGTH DECREASES WITH DEPTH OF PENETRATION
EDDY-CURRENT PATHS

AM.919

Figure 7-27.–Eddy currents produced in metal by an electromagnetic field.


EDDY-CURRENT PROBE
EDDY-CURRENT PATH AROUND CRACK
CRACK

AM.920

Figure 7-28.–Paths of eddy currents around a crack.

1. Electrical conductivity.
2. Dimensions such as rod diameters, sheet thickness, plating thickness, separation between layers, depth of corrosion product removal (by calculating the amount of remaining metal thickness against the original thickness), etc.
3. Hardness and tensile strength.
4. Magnetic permeability.
5. Detection of defects or discontinuites such as cracks, cavities, soft spots, etc.
6. Variations in tubing wall thickness or other hollow tubular parts.

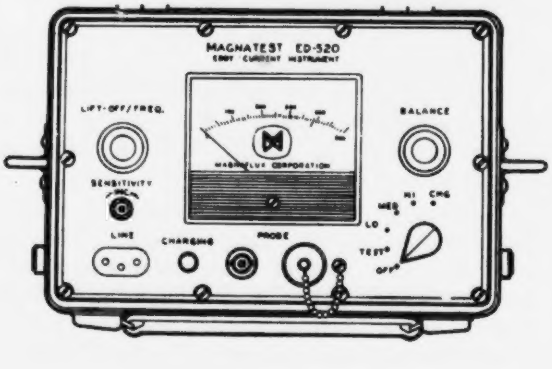
The ability to select and utilize the correct probe arrangement and interpret and mathematically calculate readout presentations necessary to provide this information requires specialized training. Class C school training requirements are covered later in this chapter.

EDDY CURRENT EQUIPMENT

There is a variety of eddy current instruments available for use by maintenance activities with accessories to accommodate most shapes, sizes, and thicknesses of materials. In this section, coverage is devoted to one of the newer models, the Magnatest ED-520.

The Magnatest ED-520, illustrated in Figure 7-29, is a compact, self-contained, lightweight, and portable instrument. It can be operated on 115- or 230-volt alternating current or from two 6-volt rechargeable internal batteries. The case is weather resistant and space is provided for storing the probe, power cord, and other accessories in the cover. It is completely adaptable to "in shop" or "on aircraft" use.

The coils or probes can include both induction and sensing fuctions so that only one need be used. On some models these functions are performed using two separate coils or probes. Coil or probe selection is dependent on the type of application. Most "on aircraft" or component inspections can be performed using surface and hole probes similar to the ones illustrated in Figure 7-30. Figure 7-31 shows the surface probe being used to inspect a hydraulic cylinder barrel. Special designed probes and coils, such as forked coils, through whose arms sheet material can pass for inspections; feed-through coils, through which rods, tubing, etc., are passed; and inside test coils or probes that are inserted into cavities such as drilled holes or hollow tubes are available to accommodate the various applications of the eddy current instrument.



AM.921

Figure 7-29.—Eddy current tester—Magnatest ED-520.

OPERATION

Prior to using the Magnetest ED-520, the operator should become thoroughly familiar with the technical manual on operation and maintenance. Insure that the instrument is properly set up for the desired operating voltage. If battery operation is selected, the charge level is checked by placing the function switch in test (Fig. 7-29). For maximum instrument stability and battery life, the instrument should not be operated when the battery charge level indicates below the red line on the meter.

The lift-off/freq. dial provides adjustment of frequency range to allow for lift-off compensation, which is an electronic technique for improving the signal-to-noise ratio. Electric signals caused by probe movement can be compensated for or suppressed to provide a more accurate sensitivity measurement.

The balance dial is used to bring the meter pointer on scale. If the pointer does not come on scale, a higher lift-off control setting is required.

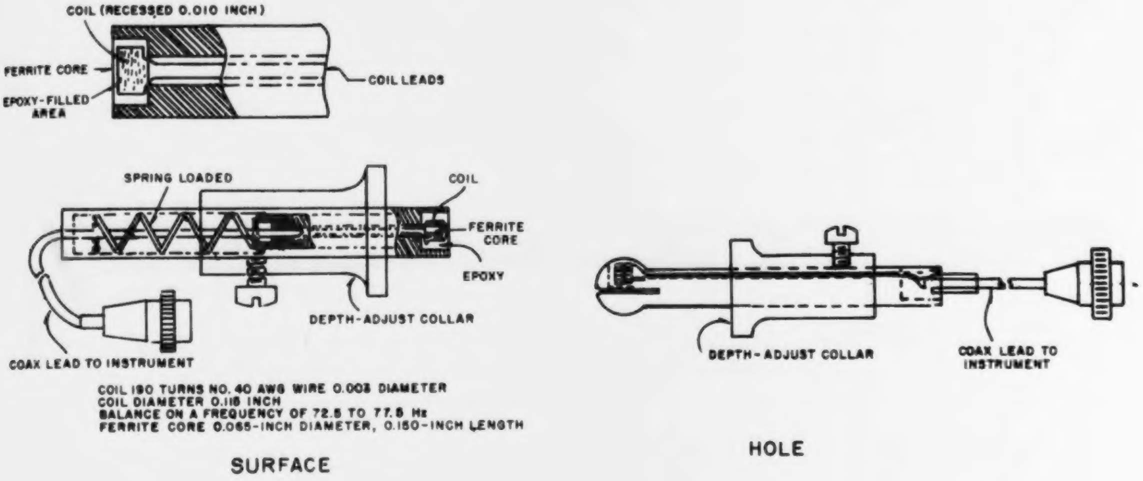
Correct probe compensation is accomplished by placing a piece of paper between the probe and the metal surface and then adjusting the meter to read constant with the paper inserted or withdrawn.

Use of a coil in lieu of a probe also requires that the coil be compensated. An uncompensated coil is indicated by the meter peaking on the scale before the test material is centered in the coil. Compensation is accomplished by adjusting the meter to peak at material center.

With the instrument properly compensated, cracks, fractures, breaks, or other flaws are generally recognized by an upscale meter deflection in magnetic materials and a downscale deflection in nonmagnetic materials. There are other types of readout devices used to present eddy current test indications to the inspector; however, readout meters similar to that of the ED-520 instrument are most common to fleet users.

SPECIAL NONDESTRUCTIVE INSPECTION TRAINING REQUIREMENTS

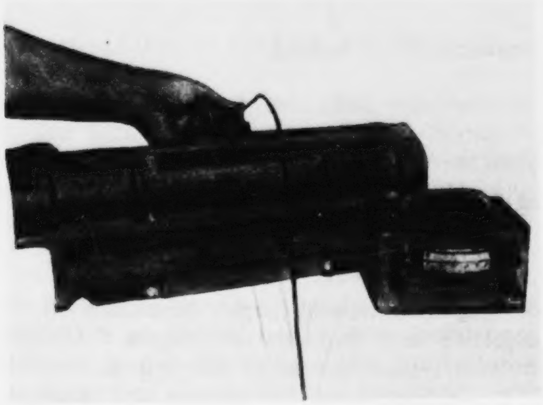
Radiographic, ultrasonic, and eddy current methods of nondestructive metal inspection


COIL (RECESSED 0.010 INCH)
FERRITE CORE
EPOXY-FILLED AREA
COIL LEADS
SPRING LOADED
COIL
FERRITE CORE
EPOXY
DEPTH-ADJUST COLLAR
COAX LEAD TO INSTRUMENT
COIL 190 TURNS NO. 40 AWG WIRE 0.003 DIAMETER
COIL DIAMETER 0.118 INCH
BALANCE ON A FREQUENCY OF 72.5 TO 77.5 Hz
FERRITE CORE 0.065-INCH DIAMETER, 0.150-INCH LENGTH
SURFACE
DEPTH-ADJUST COLLAR
COAX LEAD TO INSTRUMENT
HOLE

AM.922

Figure 7-30.—Surface and hole probes.

require extensive training before operators are considered qualified to perform reliable inspections and interpret their results. Training is presently provided for Aviation Structural Mechanics S, E-5 and above, certain Marine Corps personnel, and eligible civil service personnel at the Naval Air Technical Training Center, Jacksonville, Florida. The course, titled, Aircraft Maintenance Nondestructive Inspection, provides a basic knowledge of NDI techniques and develops skill in radiography and ultrasonic and eddy current inspection procedures over a 9-week period. Block instruction in the individual methods is also offered. Upon successful completion of the course, graduates are certified as qualified radiographers and/or ultrasonic and eddy current operators.



AM.923

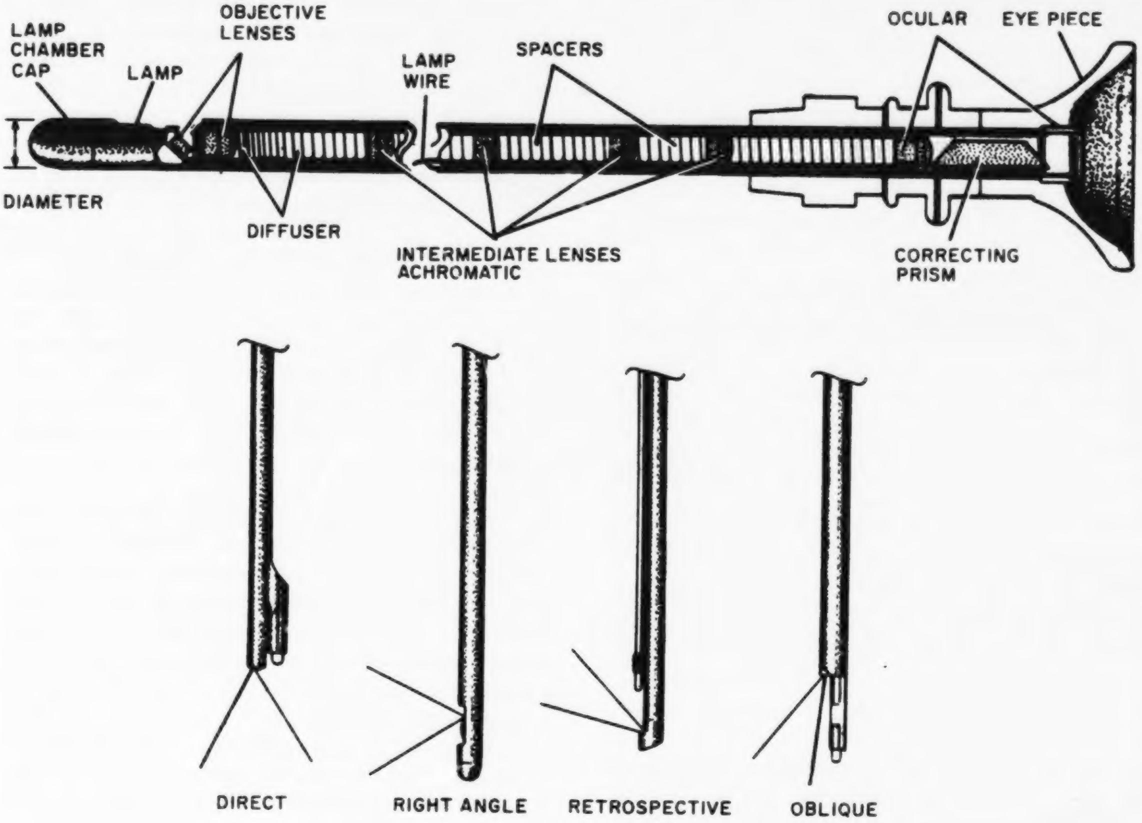
Figure 7-31.—Surface probe being used to inspect a hydraulic cylinder barrel.

OPTICAL INSPECTION

Optical inspection is the oldest form of nondestructive inspection. Some commonly used optical viewing instruments are the inspection mirror, the magnifying viewer, and the borescope. All of these instruments are available with self-illuminating features. Their use is limited to viewing surface discontinuities and in some cases to examine defects that have been discovered by other NDI techniques.

BORESCOPE

The borescope is used primarily for inspecting inaccessible areas such as internal surfaces of tubing, structural cavities, struts and actuating


LAMP CHAMBER CAP
LAMP
OBJECTIVE LENSES
LAMP WIRE
SPACERS
OCULAR
EYE PIECE
DIAMETER
DIFFUSER
INTERMEDIATE LENSES ACHROMATIC
CORRECTING PRISM
DIRECT
RIGHT ANGLE
RETROSPECTIVE
OBLIQUE

AM.924

Figure 7-32.—Typical borescope and objective lens variations.

cylinder barrels, combustion chambers, etc., for evidence of cracks or presence of corrosion or other defects. The borescope is a self-illuminating instrument provided with a power source, with attaching cord, a light connecting cord, and a protective carrying case. It contains an arrangement of prisms and lenses which allows a variety of magnified viewing angles dependent on the objective lens configuration. Figure 7-32 illustrates a typical borescope and several available lens configurations. Borescopes are available in a variety of sizes, shapes, and light sources, including ultraviolet for illuminating areas treated with fluorescent penetrants.

CHAPTER 8

OXYACETYLENE WELDING, BRAZING, AND SOLDERING

Welding is the most practical of the many metal joining processes available to aircraft manufacturers. The welded joint offers rigidity, simplicity, low weight, high strength, and low cost production equipment. Consequently welding has been universally adopted in the building of all types of aircraft. Many structural parts as well as nonstructural parts are joined by some form of welding, and the repair of these many parts is an indispensable part of aircraft maintenance.

In addition to the repair of the many aircraft parts and assemblies, there is an almost limitless variety of other welding jobs that must be done within any maintenance activity. Jobs such as fabricating jigs and fixtures and repairing maintenance equipment and machinery are common everyday duties of the AMS.

QUALIFICATIONS OF WELDERS

For advancement to first class, you must be familiar with the operation of both oxyacetylene and electric arc welding equipment and materials, and be able to perform simple welding, brazing, soldering, and cutting operations on ferrous and nonferrous metals.

In order to weld on aircraft structural parts, you must be a certified aircraft welder. To be certified as an aircraft welder, you must pass a qualification test conducted in the presence of a Navy inspector. Passing this test entitles you to a certificate signed by the inspector attesting that you are capable of welding the class of material and the type of weld indicated on the certificate.

Naval Air Rework Facilities carry on training programs for the benefit of those desiring to qualify as aircraft welders, and have facilities for conducting these tests.

OXYACETYLENE WELDING

Gas welding is a fusion process in which heat is supplied by burning a mixture of oxygen and a suitable combustion gas, usually acetylene; hence, the term oxyacetylene. A welding torch is used to mix the gases in the proper proportions and to direct the flame against the parts to be welded. The molten edges of the parts then literally flow together and, after cooling, form one solid piece. Usually it is necessary to add extra material to the joint. The correct material in rod form is dipped in and fuses with the puddle of molten metal from the parent metal parts.

Acetylene is widely used as the combustible gas because of its high flame temperature when mixed with oxygen. The temperature, which ranges from approximately 5,700° to 6,300°F, is so far above the melting point of all commercial metals that it provides a means for the rapid localized melting essential in welding. The oxyacetylene flame is also used in cutting ferrous metals. The oxyacetylene welding and cutting methods are widely used by all types of maintenance activities because the flame is easy to regulate, the gases may be produced inexpensively, and the equipment can be transported easily and safely.

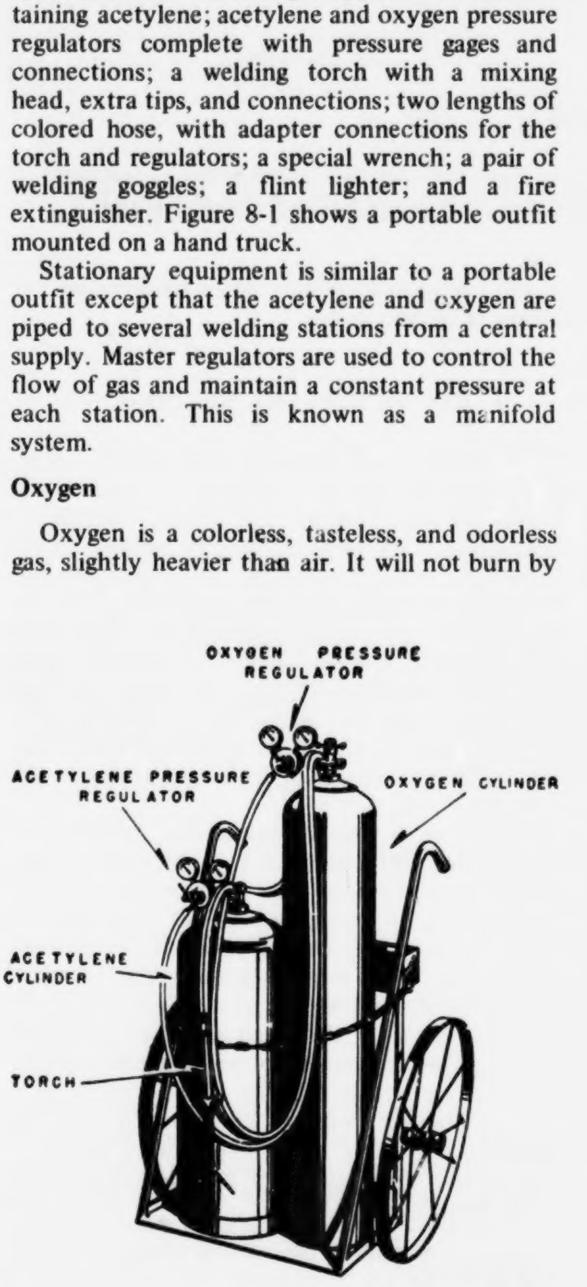
EQUIPMENT

Oxyacetylene welding equipment may be either stationary or portable. A portable outfit can be fastened on a hand truck and pushed around from job to job. It consists of two cylinders, one containing oxygen and one containing acetylene; acetylene and oxygen pressure regulators complete with pressure gages and connections; a welding torch with a mixing head, extra tips, and connections; two lengths of colored hose, with adapter connections for the torch and regulators; a special wrench; a pair of welding goggles; a flint lighter; and a fire extinguisher. Figure 8-1 shows a portable outfit mounted on a hand truck.

Stationary equipment is similar to a portable outfit except that the acetylene and oxygen are piped to several welding stations from a central supply. Master regulators are used to control the flow of gas and maintain a constant pressure at each station. This is known as a manifold system.

Oxygen

Oxygen is a colorless, tasteless, and odorless gas, slightly heavier than air. It will not burn by itself, but will support combustion by combining with other gases. This means that it aids in burning, and this burning gives off considerable heat and light. In its free state, oxygen is one of the most common elements. It makes up about 21 parts in 100 parts of air, while nitrogen accounts for 78 parts. Carbon dioxide and rare gases account for the remainder. It is the presence of oxygen in air that causes rusting of ferrous metals and the discoloration of copper and corrosion of aluminum. This action is known as oxidation. Oxygen unites with the acetylene gas in oxyacetylene welding, causing it to burn, and raising the temperature of the flame to the point where it will melt the metal.



AM.508

Figure 8-1.—Portable oxyacetylene welding outfit.

Oxygen is obtained for commercial use by one of two methods: (1) It may be obtained by the liquid-air process, in which atmospheric air is compressed and cooled until it is in a liquid state. In this state the liquid is heated slightly and pure oxygen is distilled out and compressed in cylinders. (2) Oxygen may be produced by the electrolytic process, in which the hydrogen and oxygen in water are separated by passing a direct current through the water. Hydrogen gas is collected by means of an inverted container at the negative terminal, oxygen at the positive terminal, and each is then piped off and compressed in cylinders.

Oxygen produced for welding operations is called technical oxygen. However, aviator's breathing oxygen, which is specially produced for breathing purposes, may also be used. Because of the possibility of the two types being mixed aboard ship—with unpleasant results for the aviators—aircraft carriers and other ships using breathing oxygen carry only that kind, and it is also used for welding.

Oxygen Cylinders

Standard Navy oxygen cylinders used in welding operations are made of seamless steel and come in two sizes. The smaller size holds 220 cubic feet of oxygen at 2,000 pounds per square inch (psi) pressure; the larger size holds 250 cubic feet of oxygen at 2,265 psi pressure. All oxygen cylinders are painted green for identification. Technical oxygen cylinders are solid green; breathing oxygen cylinders have a white band around the top.

Each oxygen cylinder has a high-pressure valve located at the top of the cylinder. This valve is protected by a metal safety cap which should always be in place when the cylinder is not in use.

OXYGEN SHOULD NEVER BE BROUGHT IN CONTACT WITH OIL OR GREASE. In the presence of pure oxygen, these substances become highly combustible. Oxygen hose and valve fittings should never be oiled or greased or handled with oily or greasy hands. Even grease spots on clothing may flare up or explode if struck by a stream of oxygen. Beeswax is the recommended lubricant for oxygen equipment and fittings.

Acetylene Gas

Acetylene is a flammable, colorless gas. It has a distinctive disagreeable odor that is easily detected, even when the gas is greatly diluted with air. Unlike oxygen, acetylene does not exist free in the atmosphere; it must be manufactured. The process is neither difficult nor expensive. Calcium carbide is made to react chemically with water to produce acetylene.

The gas is either used directly in a manifold system or stored in cylinders. If it is ignited in this state, the result is a yellow, smoky flame with a low temperature. When the gas is mixed with oxygen in the proper proportions and ignited, the result is a blue-white flame with a temperature of approximately 6,000°F.

Under low pressure at normal temperatures, acetylene is a stable compound; but when compressed in an empty container to pressures greater than 15 psi, it becomes dangerously unstable. For this reason, manufacturers fill the acetylene cylinders with a porous substance (generally a mixture of asbestos and charcoal) and saturate this substance with acetone. Since acetone is capable of absorbing approximately 25 times its own volume of acetylene gas, a cylinder containing the correct amount of acetone can be charged to a pressure of 250 psi without fear of the acetylene becoming unstable.

Acetylene Safety Precautions

Acetylene safety precautions should be rigidly observed and enforced. Some of the more important things to remember are as follows:

1. Store acetylene cylinders in an upright position. They must be securely fastened to prevent shifting or falling under any circumstances. Do not lay on sides, drop, or handle roughly. If horizontal stowage is necessary, or an acetylene cylinder is inadvertently left lying in a horizontal position, it must be placed in an upright position for a minimum of 2 hours before using. (Otherwise, acetone in which the acetylene is dissolved will be drawn out with the gas.) Avoid damaging the valves or fuse plugs, since this causes leakage.
2. Store acetylene cylinders in a well-protected, well-ventilated, dry place, away from heating devices or combustible materials.
3. Use acetylene from cylinders only through pressure-reducing regulators. Do not use acetylene at pressures greater than 15 psi.
4. Open the acetylene valve slowly, 1/4 to 1/2 turn. This will permit an adequate flow of gas. Never open the valve more than 1 1/2 turns of the spindle. Use the special T-wrench provided, and leave it in place on the spindle so that the acetylene may be turned off quickly in an emergency.
5. Keep sparks, flames, and heat away from acetylene cylinders.
6. Turn the acetylene cylinder so that the valve outlet will point away from the oxygen cylinder.
7. Do not interchange hose, regulators, or other apparatus intended for oxygen with those intended for acetylene.
8. Use only approved hoses and fittings with acetylene equipment. Pure cooper, or copper alloys containing 67 to 99 percent copper, must not be used in piping or fittings for handling acetylene (except blowpipe or torch tips). Acetylene reacts with pure or slightly alloyed copper to form cuprous acetylide, a violent explosive.
9. Test for leaks with soapy water–not with an open flame.
10. Make no attempt to transfer acetylene from one cylinder to another, refill an acetylene cylinder, or mix any other gas or gases with acetylene.
11. Keep valves closed on empty cylinders.
12. Should an acetylene cylinder catch fire, use a wet blanket to extinguish the fire. If this

fails, spray a stream of water on the cylinder to keep it cool.

13. Crack each cylinder valve for an instant to blow dirt out of nozzles before attaching the pressure regulator. Do not stand in front of the valve when opening it.

14. Learn to identify standard Navy cylinders by color and decals.

Acetylene Cylinders

The standard Navy acetylene cylinder is a seamless steel shell with welded ends, approximately 12 inches in diameter and 36 inches long. It is painted yellow and the name of the gas is indicated twice, once on each side of the cylinder, by 2-inch black letters painted lengthwise on the cylinder. A fully changed acetylene cylinder contains 225 cubic feet of gas at pressures up to 250 psi. In the event of fire or any excessive temperature rise, special safety fuse plugs installed in both the top and bottom of the cylinder melt, allowing the excess gas to escape or burn off, thereby minimizing the chances of an explosion. The holes in the safety plugs are made so small that they will not allow the flames to burn back into the cylinder. Acetylene cylinders should not be allowed to become completely empty, or a loss of filler material may result.

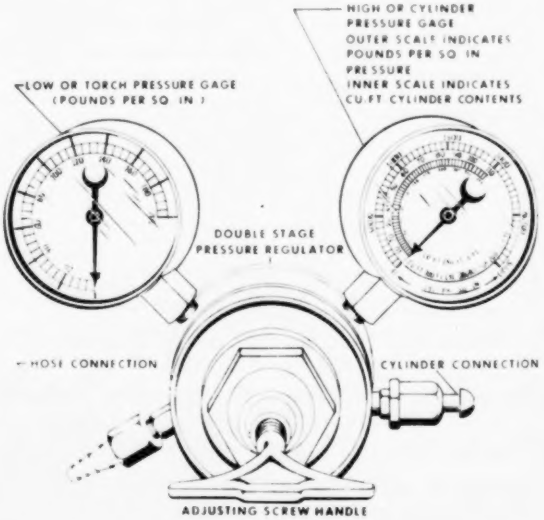
Pressure Regulators

Acetylene and oxygen regulators reduce pressures and control the flow of gases from the cylinders to the torch. Acetylene and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand such high pressures as are those designed for use with oxygen. The outlet fitting on acetylene regulators has left-hand threads to prevent interchange of hose.

In a portable welding outfit, such as that shown in **Figure 8-1**, each regulator is equipped with two pressure gages—a high-pressure gage which indicates the cylinder pressure, and a low-pressure gage which indicates the pressure in the hose leading to the torch (working pressure).

In a stationary installation, where the gases are piped to individual welding stations, only one gage for oxygen and one for acetylene are required for each welding station, because it is only necessary to indicate the working pressure of the gases flowing through the hose to the torch.

A typical regulator, complete with pressure gages and connections, is shown in Figure 8-2. The adjusting screw shown on the front of the regulator is for adjusting the working pressure. When this adjusting screw is turned to the left (counterclockwise) until it runs free, the valve mechanism inside the regulator is closed. No gas can then pass to the torch. As the handle is turned to the right (clockwise), the screw presses against the regulating mechanism, the valve opens, and gas passes to the torch at the pressure shown on the working pressure gage. Changes in this pressure may be made at will, simply by adjusting the handle until the desired pressure is registered.


HIGH OR CYLINDER PRESSURE GAGE
OUTER SCALE INDICATES POUNDS PER SQ IN PRESSURE
INNER SCALE INDICATES CU FT CYLINDER CONTENTS
LOW OR TORCH PRESSURE GAGE (POUNDS PER SQ IN)
DOUBLE STAGE PRESSURE REGULATOR
HOSE CONNECTION
CYLINDER CONNECTION
ADJUSTING SCREW HANDLE

AM.509

Figure 8-2.—Typical oxygen pressure regulator.

Before opening the valve on a cylinder, the adjusting screw on the regulator should be fully released by turning to the left. As noted previously, this closes the valve inside the regulator, thus protecting the mechanism against possible damage.

Regulators are either single-stage or two-stage type. Single-stage regulators reduce the pressure of the gases from cylinder pressure to working pressure in one step or stage. In general, its mechanism consists of a floating valve, a diaphragm, and balancing springs.

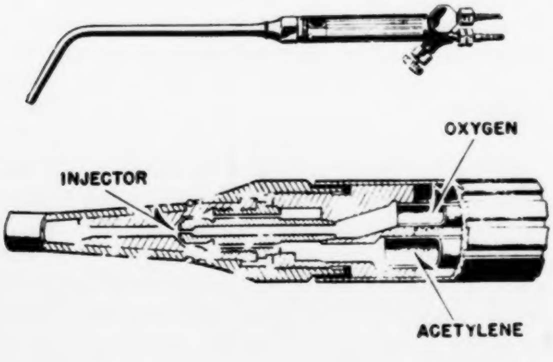
In two-stage regulators, the pressure reduction is accomplished in two separate steps. This type of regulator has two independent diaphragm and valve assemblies which make operation extremely efficient. Pressure regulators are available in both the single- and two-stage type. The two-stage type is generally used with portable outfits.

Welding Torches

The welding torch is the unit used to mix the two gases in the proper proportions and to control the volume of the gases and the direction of the flame. The torch has two needle valves–one for adjusting the flow of oxygen, the other for adjusting the flow of acetylene. In addition, a handle, two tubes, a mixing head, and a tip are provided. Tips are interchangeable and come in various styles and sizes for welding a wide range of metal thicknesses.

Welding torches may be divided into two principal classes–the balanced-pressure type and the injector type. The balanced-pressure type is also referred to as the medium-pressure torch. The injector type is sometimes referred to as the low-pressure torch. Figure 8-3 shows the internal construction of the injector type torch.

In the balanced-pressure torch, the oxygen and acetylene are both fed to the torch at the same pressure. The openings to the mixing chamber for each gas are equal in size, and the delivery of each gas is independently controlled. This type of torch is generally better suited for most welding than the injector type because of the ease of adjustment and maintenance.



AM.510

Figure 8-3.–Welding torch.

The injector type torch operates with an acetylene pressure of less than 1 psi and an oxygen pressure from 10 to 40 times greater. In some welding torches of this type, the ratio of the pressure of the oxygen to the pressure of the acetylene is 20 to 1.

A narrow passageway or nozzle within the torch, called the injector, through which the oxygen passes, causes the speed of oxygen flow to increase to a high velocity with a corresponding drop in pressure. This drop across the injector creates a pressure differential (suction) which acts to draw the required amount of acetylene into the mixing chamber in the torch head.

TORCH TIPS.–The torch tip delivers and controls the final flow of gases. It is important that the correct tip be selected and used with the proper gas pressures if a job is to be satisfactorily welded. The nature of the weld, the material, the experience of the welder, and the position in which the weld is to be made, all determine the correct size of the tip opening. The size of the tip opening, in turn, determines the amount of heat (not the temperature) applied to the work. If a tip which is too small is used, the heat provided will be insufficient to produce penetration to the proper depth. If the tip is too large, the heat will be too great and holes will be burned in the metal.

There is no standard system for indicating the size of the opening in the torch tip; each manufacturer has his own numbering system. A comparison of the tips supplied by various manufacturers appears in Table 8-1. The thickness of the metal for which each tip is adaptable is only approximate, since the nature of the weld, its position, and the conductivity of the metal are all factors in the selection of a torch tip. Such approximations may be used until the welder is experienced enough to know which size tip will produce the best weld for each situation.

With use, the torch tip will become clogged with carbon deposits and, if it is brought in

Table 8-1.—Torch tip sizes

Tip size (inches)	Tip drill size	Smith tip No.	Victor tip No.	Airco tip No.	Approximate thickness of steel sheet
0.0200	76	--------	---------	---------	1/64 - 1/32
.0210	75	--------	000	00	1/64 - 1/32
.0225	74	100	---------	---------	1/64 - 1/32
.0250	72	--------	---------	0	1/32 - 3/32
.0260	71	101	---------	---------	1/64 - 3/64
.0280	70	--------	00	---------	1/64 - 3/64
.0292	69	102	---------	---------	1/16 - 1/8
.0310	68	--------	---------	1	1/16 - 1/8
.0320	67	103	---------	---------	1/32 - 5/64
.0350	65	--------	0	---------	1/32 - 5/64
.0370	63	104	---------	---------	3/32 - 5/32
.0380	62	--------	---------	2	3/32 - 5/32
.0400	60	--------	1	---------	3/64 - 3/32
.0430	57	105	---------	---------	1/16 - 1/8
.0465	56	106	2	3	1/8 - 3/16
.0550	54	107	---------	4	5/32 - 7/32
.0595	53	--------	3	---------	1/8 - 3/16
.0635	52	108	---------	---------	1/8 - 3/16
.0670	51	--------	---------	5	3/16 - 5/16
.0730	49	109	4	---------	3/16 - 1/4
.0760	48	--------	---------	6	1/4 - 3/8

contact with the molten pool, particles of slag may lodge in the opening. A split or distorted flame is an indication of a clogged tip. Tips should be cleaned with wire tip cleaners of the correct diameter or with soft copper wire. Tips should not be cleaned with drills or other hard, sharp instruments. These devices may enlarge or scratch the tip opening and greatly reduce the efficiency of the torch tip.

Fine steel wool may be used to remove oxides from the outside of the tip. These oxides hinder the heat dissipation and cause the tip to overheat.

Welding Hose

Welding hose used in connecting the cylinders with the torch are specially made for the purpose. Oxygen hose is either green or black, and acetylene hose is red or maroon. The hoses are attached to their respective regulators at one end and to the torch at the other. Acetylene hose fittings have left-hand threads and the nut is marked with a groove. Oxygen hose fittings have right-hand threads, and the nut is plain.

Lighters

A flint lighter is provided for igniting the torch. The lighter consist of a file-shaped piece of steel, usually recessed in a cuplike device, and a piece of flint that can be drawn across the steel, producing the sparks required to light the torch. CAUTION: Matches should never be used to ignite a torch; their length requires bringing the hand too close to the tip in order to ignite the gas. Accumulated gas may envelop the hand and, when ignited, cause a severe burn.

Goggles

Welding goggles are fitted with colored lenses to keep out heat and light rays and to protect the eyes from sparks and molten metal. Regardless of the shade of lens used, it should be protected by a clear cover glass. The welding operator should select the shade or density of color that is best suited to him for his particular work. The desired lens is the one of the darkest shade which will show a clear definition of the work without eyestrain. Goggles should fit closely around the eyes and should be worn at all times during welding and cutting operations.

Special goggles, utilizing standard lenses, are available for use with spectacles.

Welding (Filler) Rods

The use of the proper type filler rod is very important in oxyacetylene welding operations. This material not only adds reinforcement to the weld area, but also adds desired properties to the finished weld. By selecting the proper type rod, either tensile strength or ductility can be secured in a weld, or both can be secured to a reasonably high degree. Similarly, rods can be selected which will help retain the desired amount of corrosion resistance. In some cases, a suitable rod with a lower melting point will eliminate possible cracks from expansion and contraction.

Welding rods may be classified as ferrous and nonferrous. The ferrous rods include carbon and alloy steel rods as well as cast iron rods. Nonferrous rods include brazing and bronze rods, aluminum and aluminum alloy rods, magnesium and magnesium alloy rods, copper rods, and silver rods.

Welding rods are manufactured in standard 24-inch and 36-inch lengths and in daimeters from 1/16 inch to 3/8 inch. The diameter of rod used is governed by the thickness of the metals being joined. If the rod is too small, it will not conduct heat away from the puddle rapidly enough, and a burned weld will result. A rod that is too large will chill the puddle. As in selecting the proper size welding torch tip, experience will enable the welder to select the proper diameter welding rod.

WELDING FLAMES

The welding flame is classified as neutral, oxidizing, or carburizing, each having its own special function. Adjustment of the torch enables the operator to produce the type of flame best suited for the job at hand.

The neutral flame, in which a balanced mixture of oxygen and acetylene is burned, is used for most welding operations. The oxidizing flame, in which an excess of oxygen is burned is used for welding bronze or fusing brass and bronze. The carburizing flame, in which an excess of acetylene is burned, is used when welding nickel alloys.

Neutral Flame

The neutral flame does not alter the composition of the base metal to any great extent and is therefore the best suited for most metals. The neutral flame burns at approximately 5,850°F. A balanced mixture of one volume of oxygen and one volume of acetylene is supplied from the torch when the flame is adjusted to neutral.

As shown in **Figure 8-4**, the neutral flame is divided into two distinct zones. The inner zone consists of the cone–a white, clearly defined, round, smooth cone, 1/16 to 3/4 inch in length. The outer zone, made up of completely burned oxygen and acetylene, is blue with a purple tinge at the point and edges.

A neutral flame melts metal without changing its properties and leaves the metal clear and clean. If the mixture of oxygen and acetylene is correct, the neutral flame allows the molten metal to flow smoothly, and few sparks are produced when welding most metals.

Carburizing Flame

The carburizing flame, produced by burning an excess of acetylene, may be recognized by its three distinct colors. There is a bluish-white inner cone, a white intermediate cone, and a light-blue outer flame. It may be recognized also by the feather at the tip of the inner cone. (See Fig. 8-4.) The degree of carburization can be judged by the length of the feather.

Acetylene burning in air. 1,500° F.

Strongly Carburizing Flame. 5,700° F.

Slight Excess Acetylene Flame. 5,800° F.

Neutral Flame. 5,900° F.

Oxidizing Flame. 6,300° F.

Courtesy Air Reduction Sales Co.

AM.511

Figure 8-4.—Characteristics of oxyacetylene flames. Courtesy of Air Reduction Sales Co.

Oxidizing Flame

The oxidizing flame is produced by burning an excess of oxygen. It has the general appearance of the neutral flame, but the inner cone is shorter, slightly pointed, and has a purplish tinge. (See Fig. 8-4.) This flame burns with a hissing sound. An oxidizing flame can be recognized when welding ferrous metals by the numerous sparks which are thrown off as the metal melts and by the foam or scum which forms on the surface.

Flame Adjustment

To adjust the flame, light the torch by opening the torch acetylene valve 1/4 to 1/2 turn. With only the acetylene valve open, the flame will be yellow in color and will give off smoke and soot.

Now open the torch oxygen valve slowly. The flame will gradually change in color from yellow to blue and will show the characteristics of the excess acetylene flame described earlier.

With most torches, there will still be a slight excess of acetylene when the oxygen and acetylene valves are wide open and the recommended pressures are being used. Now close the acetylene valve on the torch very slowly. It will be noticed that the secondary cone gets smaller until it finally disappears completely. Just at this point of complete disappearance the neutral flame is formed.

In order to see the effect of an excess of oxygen, close the acetylene valve still further. A change will be noted, although it is by no means as sharply defined as that between the neutral and excess acetylene flames. The entire flame will decrease in size, and the inner cone will become much less sharply defined.

Because of the difficulty in making a distinction between the excess oxygen and neutral flames, an adjustment of the flame to neutral should always be made from the excess acetylene side. Always adjust the flame first so that it shows the secondary cone characteristic of excess acetylene, then, increase the flow of oxygen until this secondary cone just disappears.

During actual welding operations, where a neutral flame is essential, the flame should be checked occasionally to make certain it is neutral. This is accomplished by momentarily withdrawing the torch from the work and increasing the amount of acetylene until a distinctive feathery edge appears on the inner cone. Then, slowly decrease the amount of acetylene until a well-defined cone, characteristic of the neutral flame, is formed.

With each size of tip, a neutral, oxidizing, or carburizing flame can be obtained. It is also possible to obtain a "harsh" or "soft" flame by increasing or decreasing the pressure of both gases.

For most regulator settings the gases are expelled from the torch tip at a relatively high velocity, and the flame is called "harsh." For some work it is desirable to have a "soft" or low velocity flame without a reduction in thermal output. This may be achieved by using a larger tip and closing the gas needle valves until the neutral flame is quiet and steady. It is especially desirable to use a soft flame when welding aluminum, to avoid blowing holes in the metal when the puddle is formed.

BACKFIRE AND FLASHBACK

Improper handling of the torch may cause the flame to backfire or, in very rare cases, to flashback. A backfire is a momentary backward flow of the gases at the torch tip, causing the flame to go out. Sometimes the flame may immediately come on again, but a backfire is always accompanied by a snapping or popping noise. A backfire may be caused by touching the tip against the work, by overheating the tip, by operating the torch at other than recommended pressures, by a loose tip or head, or by dirt or slag in the end of the tip. A backfire is rarely dangerous, but the molten metal may be splattered when the flame pops.

A flashback is the burning of the gases within the torch and is dangerous. It is usually caused by loose connections, improper pressures, or overheating of the torch. A shrill hissing or squealing noise accompanies a flashback; and unless the gases are turned off immediately, the flame may burn back through the hose and regulators and cause great damage. The cause of a flashback should always be determined and the trouble remedied before relighting the torch.

SETTING UP EQUIPMENT

Setting up welding equipment and preparing for welding must be done systematically and in a definite order to avoid costly mistakes. Follow the instructions listed below, in the order given, to assure your own safety and the safety of the equipment.

1. Secure the cylinders so they cannot be upset. Remove the protecting caps from the cylinders, then the outlet connection caps.
2. Crack the cylinder valves by opening each valve for an instant to blow it out clean. Close the valves and wipe off the connections with a clean cloth.

3. Connect the acetylene pressure regulator to the acetylene cylinder and the oxygen regulator to the oxygen cylinder. Use a regulator wrench and tighten the connecting nuts tight enough to prevent leakage.

4. Connect the red (or maroon) hose to the acetylene pressure regulator and the green (or black) hose to the oxygen regulator. Tighten the connecting nuts tight enough to prevent leaks. (Notice the left-hand threads on the acetylene hose connections. Do not force, as these threads are made of brass and are easily damaged.)

5. Release both pressure regulator adjusting screws by turning the adjusting screw handle on each regulator counterclockwise until it runs free. (This is to avoid damage to the regulators and pressure gages when the cylinder valves are opened.)

6. Open the cylinder valves slowly and read each of the cylinder pressure gages to check the contents in each cylinder.

CAUTION: Stand to one side of the regulator while opening a cylinder valve to avoid possible injury.

7. Blow out each hose by turning the pressure adjusting screw handle inward (clockwise) and then turning it out again.

CAUTION: Acetylene hose should be blown out only in a well-ventilated space, free from sparks, flame, or other sources of ignition.

8. Connect both hoses to the torch and check the connections for leaks by turning the pressure regulator screws in, with the torch needle valves closed. When 20 psi shows on the oxygen working pressure gage and 5 psi on the acetylene gage, close the valves by turning the pressure regulator screws out. A drop in pressure on the working gage indicates a leak between the regulator and torch tip. A general tightening of all connections should remedy the situation. If it becomes necessary to locate the leak, use the soapsuds method. Do this by painting all fittings and connections with a thick solution of soapy water.

CAUTION: Do not hunt for an acetylene leak with a flame as a serious explosion can occur in the hose or in the cylinder.

9. Adjust the working pressure on both the oxygen and acetylene regulators by turning the pressure adjusting screw on the regulator clockwise until the desired settings are obtained.

10. Light the torch, using the friction lighter provided. The torch is lighted by opening the acetylene needle valve and igniting the acetylene as it leaves the torch tip. Adjust the flame for the welding operation at hand, as described earlier. CAUTION: When lighting the torch, always point the tip AWAY from your body, other persons, and flammable materials.

SHUTTING DOWN

Extinguish the torch flame by closing the acetylene needle valve first, then close the oxygen needle valve.

When welding is stopped and will not be resumed within 15 minutes, or when the equipment is to be left unattended for any period of time, the equipment must be secured as follows:

1. Extinguish the torch as described previously.

2. Close both acetylene and oxygen cylinder valves. (Leave regulators open momentarily.)

3. Open acetylene valve on torch and allow gas to escape (5-15 seconds) to outside atmosphere. NOT into small or closed compartment. Close valve.

4. Open oxygen valve on torch and allow gas in hose to escape (5-10 seconds). Close valve.

5. Close both regulators. NOTE: Regulators are closed when adjusting screws are backed out (turned counterclockwise) until loose.

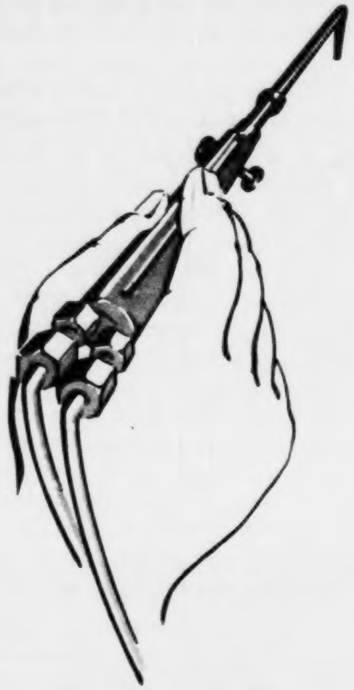
NOTE: This procedure for shutting down welding equipment is taken from NAVMAT P-5100, Safety Precautions for Shore Activities, and is therefore mandatory.

FUNDAMENTAL WELDING TECHNIQUES

The composition, thickness, shape, and position of the metal to be welded govern the techniques to be used. Techniques applying to the composition of the metal are covered later in this chapter. The fundamental techniques applying to different thicknesses, shapes, and positions of the metal to be welded are discussed in the following paragraphs.

Holding the Torch

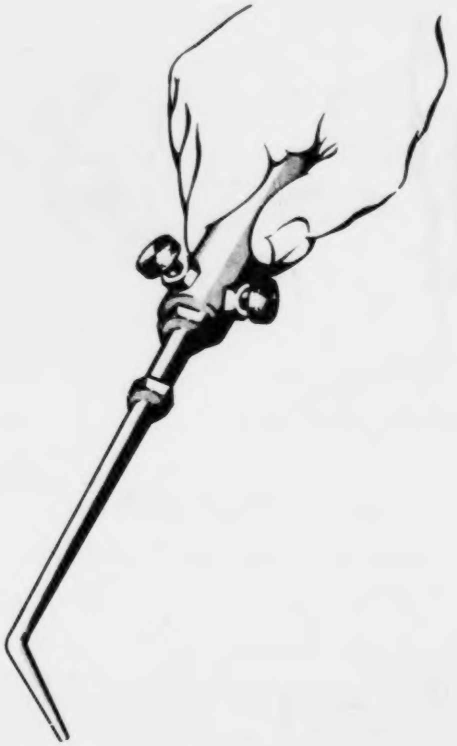
The proper method to use in holding the torch depends upon the thickness of the metal being welded. For light gage metal, hold the torch as shown in Figure 8-5, with the hose draped over the wrist. For heavier work, hold the torch as shown in Figure 8-6.



AM.512
Figure 8-5.—Welding light-gage metals.

Hold the torch so that the tip is in line with the joint to be welded, and inclined between 30 and 60 degrees from the perpendicular. The exact angle depends upon the type of weld to be made, the amount of preheating necessary, and the thickness and type of metal. The thicker the metal, the more nearly vertical the torch must be for proper heat penetration. The white cone of the flame should be held about 1/8 inch from the surface of the base metal.

If the torch is held in the correct position, a small puddle of molten metal will form. The puddle should be composed of equal parts of the two pieces being welded. After the puddle appears, begin the movement of the tip in a semicircular or circular motion. This movement assures an even distribution of heat on both pieces of metal. The speed and motion of the torch are learned only by practice and experience.



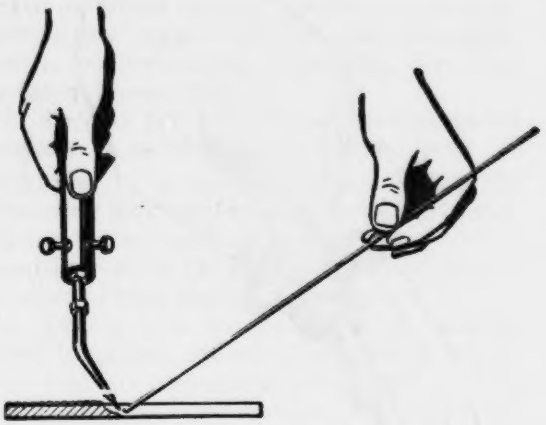
AM.513
Figure 8-6.—Welding heavy plate.

Forehand Welding

Forehand welding is the technique of pointing the torch flame forward in the direction in which the weld is progressing. The filler rod is added to the puddle as the edges of the joint melt before the flame. (See Fig. 8-7.) The forehand method is used in welding most of the lighter tubings and sheet metals, or when the weld is to be made in certain positions.

Backhand Welding

Backhand welding is the technique of pointing the torch flame toward the finished weld and

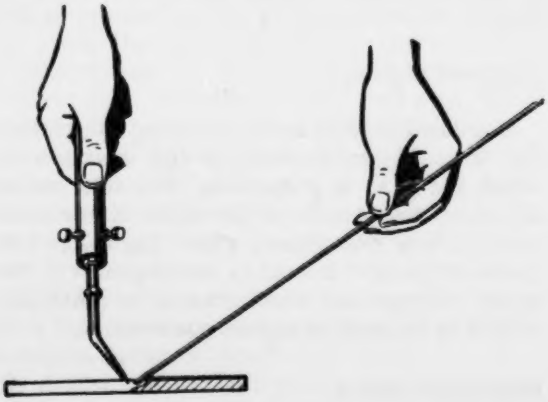


AM.514

Figure 8-7.--Forehand welding.

moving away in the direction of the unwelded area, melting the edges of the joint as it is moved. (See Fig. 8-8). The welding rod is added to the puddle between the flame and the finished weld.

Backhand welding is seldom used on sheet metal because the increased heat generated in this method is likely to cause overheating and burning. It is preferred for metals having a thick cross section. The large puddle of molten metal required for such welds is more easily controlled in backhand welding, and it is possible to examine the progress of the weld and determine if penetration is complete.



AM.515

Figure 8-8.—Backhand welding.

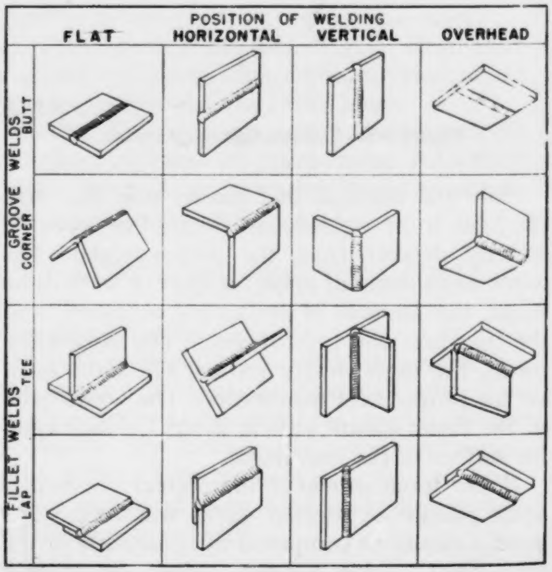
Welding Positions

The four basic welding positions are shown in Figure 8-9. Also shown are four commonly used joints. Notice that the corner joint and butt joint are classified as groove welds, while the tee and lap joints are classified as fillet welds.

Welding is always done in the flat position whenever possible. The puddle is much easier to control, and the welder can work longer periods without tiring. Quite often though, it is necessary to weld in the overhead, vertical, or horizontal position in equipment repair.

The flat position is used when the material is to be laid flat or almost flat and welded on the topside. The welding torch is pointed downward toward the work. This weld may be made by either the forehand or backhand technique.

The overhead position is used when the material is to be welded on the underside with the torch pointed upward toward the work. In welding overhead, the puddle can be kept from sagging if it is not permitted to get too large or



AM.516

Figure 8-9.—Four basic welding positions.

assume the form of a large drop. The rod is used to control the molten puddle. The volume of flame used should not be permitted to exceed that required to obtain a good fusion of the base metal with the filler rod. Less heat is required in an overhead weld because the heat naturally rises.

The horizontal position is used when the line of the weld runs horizontal across a piece of work, and the torch is directed at the material in a horizontal or near horizontal position. The weld is made from right to left across the plate (for the right-hand welder). The flame is inclined upward at an angle of from 45 to 60 degrees, and the weld is made with a normal forehand technique. Adding the rod to the top of the puddle will prevent the molten metal from sagging to the lower edge of the bead. If the puddle is to have the greatest possible cohesion, it should not be allowed to get too hot.

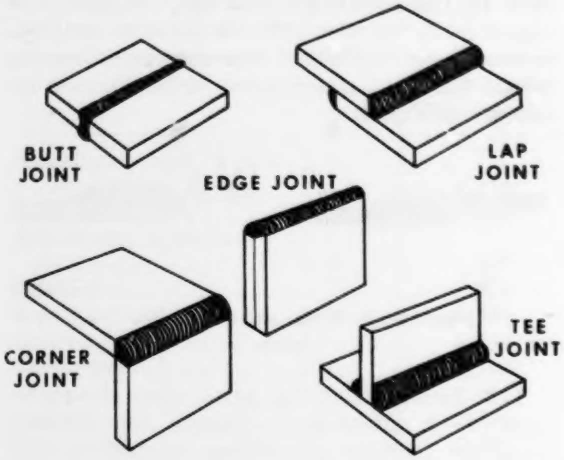
In a vertical weld, the pressure exerted by the torch flame must be relied upon to a great extent to support the puddle. It is highly important to keep the puddle from becoming too hot, in order to prevent the hot metal from running out of the puddle onto the finished weld. It may be necessary to remove the flame from the puddle for an instant to prevent overheating, and then return it to the puddle. Vertical welds are begun at the bottom, and the puddle is carried upward with a forehand motion. The tip should be inclined from 45 to 60 degrees, the exact angle depending upon the desired balance between correct penetration and control of the puddle. The rod is added from the top and in front of the flame with a normal forehand technique.

WELDED JOINTS

The five fundamental types of welded joints are the butt joint, tee joint, lap joint, corner joint, and edge joint. (See Fig. 8-10.)

Butt Joints

A butt joint is made by placing two pieces of material edge to edge, so that there is no overlapping, and then welding. Some of the various types of butt joints are shown in Figure 8-11. The flanged butt joint is used in welding thin sheets, 1/16 inch or less. The edges are prepared for welding by turning up a flange equal to the thickness of the metal. This type is usually made without the use of filler rod.



AM.517

Figure 8-10.—Types of welded joints.

A plain butt joint is used for metals from 1/16 to 1/8 inch in thickness. A filler rod is used in making this joint in order to obtain a strong weld.

If the metal is thicker than 1/8 inch, it is necessary to bevel the edges so that the heat from the torch can penetrate completely through the metal. These bevels may be either single or double bevel types or single or double V-type. The U-type joint is generally used on very thick metals. A filler rod is used to add strength and reinforcement to the weld.

Lap Joints

The lap joint is seldom used in oxyacetylene welding of flat stock, but is commonly used in

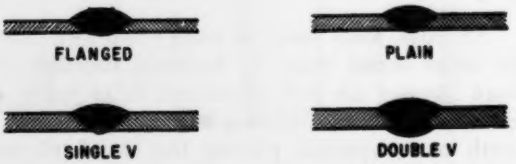


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Figure 8-11.—Types of butt joints.

spot welding. The single fillet lap joint, shown in Figure 8-12, has very little resistance to bending, and will not withstand the shearing stress to which the weld is subjected under tension or compression loads.

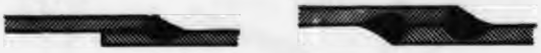

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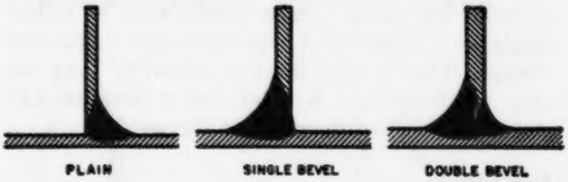
Figure 8-12.–Single and double fillet lap joints.

The double fillet lap joint, also shown in Figure 8-12, offers more strength, but requires twice the amount of welding required on the simpler, more efficient butt weld.

Tee Joints

A tee joint is formed when the edge or end of one piece is welded to the surface of another, as shown in Figure 8-13. These joints are quite common in tubular structures. The plain tee joint is suitable for thin plate metal but heavier metals require the vertical member to be single or double beveled, in order to permit the heat to penetrate deeply enough. The dark areas in the illustrations show the depth of heat penetration and fusion required.



AM.520

Figure 8-13.–Types of tee joints.

Edge Joints

An edge joint may be used when two pieces of sheet metal must be fastened together and load stresses are not important. Edge joints are usually made by bending the edges of one or both parts upward, placing the two bent ends parallel to each other or placing one bent end parallel to the upright unbent end, and welding along the outside of the seam formed by the two joined edges. Figure 8-14 shows two types of edge joints. The type shown in (A) requires no filler rod, since the edges can be melted down to fill the seam. The type shown in (B) being thicker metal, must be beveled for heat penetration and filler rod added for reinforcement.

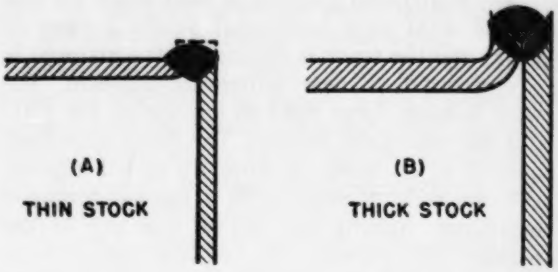


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Figure 8-14.–Types of edge joints.

Corner Joints

A corner joint is made when two pieces of metal are brought together so that their edges form a corner of a box or enclosure as shown in Figure 8-15.

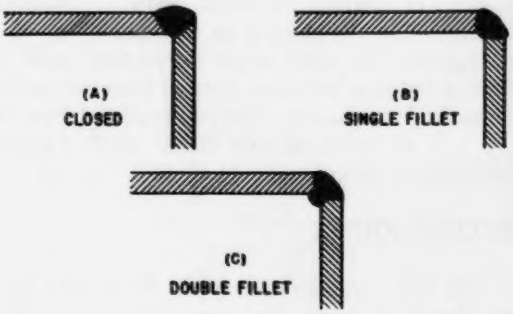

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Figure 8-15.–Types of corner joints.

The corner joint shown in (A) requires little or no filler rod, since the edges fuse to make the weld. It is used where load stress is unimportant. The joint shown in (B) is used on heavier metals, and filler rod is added for roundness and strength. If much stress is to be placed on the corner, the inside is reinforced as shown in (C).

MELTING POINT

The melting point of any substance is the temperature at which the solid substance becomes liquid. Pure metals have a constant melting point, but when alloyed with other metals or chemicals, the melting point is changed. The amount of the change depends upon the percentage and melting point of the alloying elements. A welder should know the approximate melting points of the various metals because it is often necessary to weld together metals which differ in this respect. Table 8-2 shows the melting point of the most commonly used aircraft metals.

EXPANSION AND CONTRACTION

Heat causes metals to expand; cooling causes them to contract. Uneven heating will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions stresses are set up within the metal. These forces must be relieved, and unless precautions are taken, warping or buckling of the metal takes place. Likewise, on cooling, if nothing is done to take up the stress set up by the contraction forces, further warping may result; or if the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling or may remain within the metal until further force is applied, as when the piece is put into use.

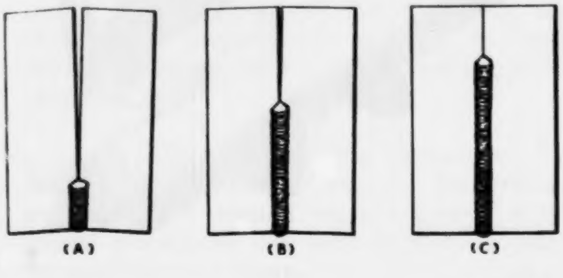
Sheet metal (1/8 inch and less in thickness) has such a large surface area per unit of weight, heat stresses tend to produce warping or buckling of the sheet. This and the contraction effect encountered on long seams are the main points to be considered in sheet metal welding.

The effect of welding a long seam (over 10 or 12 inches) is to draw the seam together as the weld progresses. If the edges of the seam are placed in contact with each other throughout their length before welding starts, the far ends of the seam will actually overlap before the weld is completed.

One way of overcoming this effect is illustrated in Figure 8-16. The two pieces to be

Table 8-2.–Melting points of aircraft metals

Metal	Melting point (degrees F.)
Aluminum, cast, 8 percent copper	1,175
Aluminum, pure	1,218
Aluminum, 5 percent silicon	1,117
Bismuth	520
Brass	1,660
Bronze	1,598
Chromium	2,740
Copper	1,981
Inconel	2,540
Iron, cast	2,300
Iron, Malleable	2,300
Iron, wrought	2,900
Lead	620
Magnesium	1,240
Molybdenum	4,532
Nickel	2,646
Silver	1,762
Steel, high carbon	2,500
Steel, low carbon	2,700
Steel, medium carbon	2,600
Steel, manganese	2,450
Steel, nickel	2,600
Steel, cast	2,600
Stainless steel	2,640
Tin	450
Titanium	3,270
Vanadium	3,182
Zinc, cast or rolled	786


(A) (B) (C)

AM.523

Figure 8-16.–Allowance for straight butt weld.

welded are placed with an increased allowance at the far end; and as the welding progresses, the two pieces are drawn together. This allowance is generally one metal thickness per foot of seam.

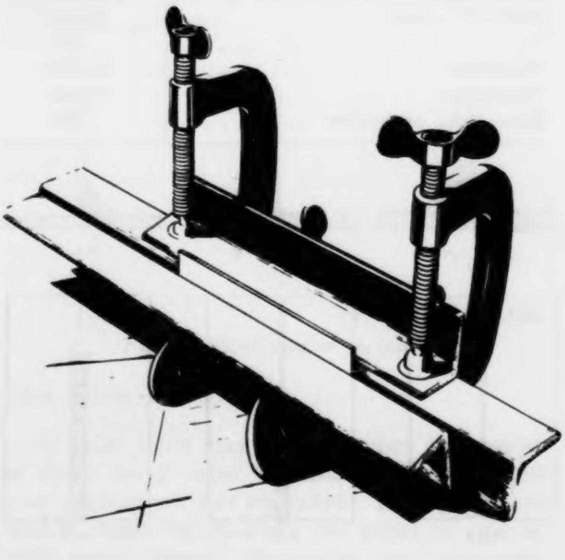
Another method of controlling expansion and contraction is by the use of chill bars. Heavy pieces of metal are placed on either side of the weld; they absorb the heat and keep it from spreading across the whole surface area. Copper is commonly used for chill bars because of its ability to absorb heat readily. Welding jigs sometimes use this same principle to remove heat from the base metal. (See Fig. 8-17.)

Preheating is another method of controlling expansion and contraction. Preheating is especially important in welding tubular structures and also in welding castings. Contraction still takes place at the weld, but there is also shrinking in the rest of the structure at approximately the same rate.

CHARACTERISTICS OF A GOOD WELD

A completed weld should have the following characteristics:

1. The seam should be smooth, the bead ripples evenly spaced, and of a uniform thickness.



AM.524

Figure 8-17.—Example of the use of jigs and chill bars.

2. The weld should be built up, thus providing extra thickness at the joint.
3. The weld should taper off smoothly into the base metal.
4. No oxide should be formed on the base metal close to the weld.
5. The weld should show no signs of blowholes, porousness, or projecting globules.
6. The base metal should show no signs of burns, pits, cracks, or distortion.

Although a clean, smooth weld is desirable, this characteristic does not necessarily mean that the weld is a good one; it may be dangerously weak inside. However, when a weld is rough, uneven, and pitted, it is almost always unsatisfactory inside. Welds should never be filed to give them a better appearance, since filing deprives the weld of part of its strength. Nor should they be filled with solder, brazing material, or filler of any sort.

When it is necessary to reweld a joint, all old weld material must be removed before the operation is begun. It must be remembered though, that reheating the area causes the base metal to lose its strength and become brittle.

WELDING FERROUS METALS

Low-carbon steel, low-alloy steel, cast steel, and wrought iron are easily welded with the oxyacetylene flame. Plain, low-carbon steel is the ferrous material that will be gas welded most frequently. As the carbon content of steel increases, welding becomes more difficult. For this reason parts made of steel may be repaired by welding only under certain conditions. Factors involved are carbon content and hardenability. For corrosion and heat resistant nickel-chromium steels, the allowed weldability depends upon their stability, carbon content, or reheat treatment.

Before attempting a repair which includes the welding of steels, the appropriate military specification should be consulted.

Preparation for Welding

Proper preparation for welding is an important factor in every welding operation. The edges of the parts must be prepared in accordance with the joint design chosen. The edges must be CLEAN. Arrangements must be made for holding the parts in proper alignment and for preheating, if this is required.

The first step in preparing a part for welding is to strip it of all dirt, grease or oil, and any protective coating such as cadmium plating, enamel, paint, or varnish. Such coatings not only hamper welding, but also mingle with the weld to prevent good fusion.

Cadmium plating can be chemically removed by dipping the edges to be welded in a mixture of 1 pound of ammonium nitrate and 1 gallon of water.

Enamel, paint, or varnish may be removed by sandblasting, by using paint or varnish remover, or by treating the pieces with a 10 percent caustic soda solution followed by a thorough washing with hot water to remove the solvent or residue.

Sandblasting is the most effective method for removing rust or scale from steel parts. Grease or oil may be removed with a suitable grease solvent.

Welding Techniques

As stated previously, some types of ferrous metals are more difficult to weld than others. For this reason, the techniques used for welding these metals differ in some respects. Therefore, the techniques for welding various types of ferrous metals are covered separately in the following paragraphs.

CARBON STEELS.–In general, the carbon steels that are weldable require no preheating, and no flux is required. Use a low-carbon steel filler rod containing a small percentage of vanadium. Carefully adjust the torch flame to neutral.

Use the forehand method, holding the torch at an angle of 60 degrees to the surface of the work. Be sure that the tip of the inner cone of the flame does not quite touch the molten metal. If the edges of the metal have been beveled, use a swinging motion of the torch to melt the metal on each side of the groove.

While breaking down the edges, grasp the filler rod in the other hand and hold it in the outer cone of the flame to heat it. The filler rod should almost reach the melting point by the time that the puddle of molten metal has formed in the bottom of the groove.

Move the torch in one direction while moving the rod in the opposite direction. Dip the tip of the filler rod below the surface of the weld puddle just before the rod begins to melt, and move it from side to side in the puddle with a motion exactly opposite to the motion of the torch. If the filler rod is held above the surface of the puddle, it will melt and fall into the puddle a drop at a time. This ruins the weld.

Add filler metal until the surface of the joint is built up slightly above the edges of the parts being joined. Gradually advance the puddle of molten metal along the seam until the end is reached.

As the end of the seam is approached, raise the torch slightly, chilling the molten steel to prevent it from spilling over the edge and/or melting through the work.

CHROME-MOLYBDENUM STEEL.–The welding technique for chrome-molybdenum is practically the same as that for carbon steels, except that the surrounding area must be preheated to a temperature between 300° and 400°F before beginning to weld. To preheat the metal, direct the flame at such an angle that preheating takes place just ahead of the weld. Use a rod of the same material as the base metal. Use a soft neutral to slightly carburizing flame just large enough to melt the base metal and to obtain good fusion.

If jigs or fixtures are used, they should be designed to prevent any strains from contraction while the metal is cooling. In other words, the metal should not be clamped too tight.

Chrome-molybdenum thicker than 0.093 inch should be electric arc welded. In electric arc welding, the heat zone is narrower, the heat strains are lower, and a better weld will be obtained.

STAINLESS STEEL.–The procedure for welding stainless steel is basically the same as that for carbon steels. There are, however, some special precautions that must be taken in order to obtain the best results.

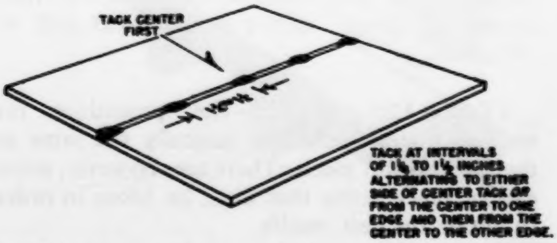
Only stainless steel used for nonstructural members can be welded satisfactorily; the stainless steel used for structural components is cold-worked or cold-rolled and, if heated, loses some of its strength. Nonstructural stainless steel is obtained in sheet and tubing form and is often used for exhaust collectors, stacks, or manifolds. Oxygen combines very readily with this metal in the molten state, and extreme care must be taken to prevent this combination.

A slightly carburizing flame is recommended for welding stainless steel, and the welder should adjust the flame so that a feather of excess acetylene, about 1/16-inch long, forms around the inner cone. Too much acetylene, however, will add carbon to the metal and cause it to lose its resistance to corrosion. The torch tip size should be one or two sizes smaller than that prescribed for a similar gage of plain steel. The smaller tip lessens the chances of overheating and subsequent loss of the "stainless" qualities of the metal.

Thin sheets which are to be butt welded should be tacked at intervals of 1 1/4 to 1 1/2 inches, as shown in Figure 8-18. This is one means of lessening warping and distortion during the welding process.

Stainless steel must be protected from the atmosphere to prevent the nitrogen and oxygen in the air from combining with the hot metal. This is done by welding in an atmosphere of inert gas, or by using a suitable flux. Flux for gas welding of corrosion-resistant or heat-resistant alloys must conform to the requirements of Specification MIL-F-7516B. Fluxes must not increase the carbon content of the weld metal significantly.

The flux used with stainless steel is compounded especially to dissolve the chromium oxide which forms on the molten metal. It is mixed with water until it forms a thin paste. Apply the flux to the underside of the seam and to the filler rod. Allow the flux to dry a few minutes after brushing it on.


TACK CENTER FIRST
TACK AT INTERVALS OF 1¼ TO 1½ INCHES ALTERNATING TO EITHER SIDE OF CENTER TACK OR FROM THE CENTER TO ONE EDGE AND THEN FROM THE CENTER TO THE OTHER EDGE.

AM.525

Figure 8-18.—Tacking methods.

If the pieces to be welded are thinner than 0.063 inch, turn up flanges on each edge to a height equal to the metal thickness. The flanges will melt down and furnish enough metal to fill the seam.

For stainless steel from 0.063 to 0.093 inch thick, use a plain butt joint and place a backing strip of copper beneath the seam to prevent the molten metal from flowing out of the weld and to absorb some of the heat. Use a filler rod of the same material as the base metal.

Stainless steel thicker than 0.093 inch should be electric arc welded if possible; but if it must be oxyacetylene welded, bevel the edges to form a V-type butt joint.

WELDING NONFERROUS METALS

Aluminum Alloys

Gas welding of aluminum alloy is usually confined to materials from 0.031 to 0.125 inch in thickness. Thicker material may be gas welded if necessary, but thinner material is usually spot or seam welded.

Aluminum alloys best suited for gas welding are 1100, 3003, 5052, 6056, 6061, and 6063. Gas welding of 2014, 2017, 2024, and 7075 is not permitted, since the strength of the metal in the vicinity of the weld is lowered considerably and cannot be restored. Corrosion resistance is also seriously impaired.

MELTING CHARACTERISTICS OF ALUMINUM.—Before attempting to weld aluminum alloy for the first time, it is advisable to become familiar with the action of the metal under the welding flame.

Place a small piece of sheet aluminum on the welding table, light the torch, and adjust the flame to neutral. With the flame held perpendicular to the surface of the sheet, bring the tip of the inner cone almost in contact with the metal. Observe that almost without warning the metal suddenly melts and runs away leaving a hole in the sheet. Now repeat the operation with the torch held at an angle of about 30 degrees to the plane of the surface. With a little practice, you will be able to melt the surface metal without forming a hole. Now try moving the flame slowly along the surface of the sheet, melting a small puddle. Observe how quickly the puddle solidifies when the flame is removed. Continue this practice until able to control melting, then proceed with practice in actual welding, starting with simple flanged and notched butt joints which do not require welding rod. Then proceed with the use of welding rod, at first with thin sheet and subsequently with castings.

PREPARATION OF ALUMINUM FOR WELDING.–Thickness of the material determines the method of edge preparation. On material up to 0.062 inch, the edges should be formed to a 90-degree flange about the same height as the thickness of the material or higher. (See (A) of Fig. 8-19.) The only requirement for the flanges is that the edges be straight and square. If desired, material up to 0.125 inch may be welded with a flange type joint. No filler rod is necessary when the edges are flanged.

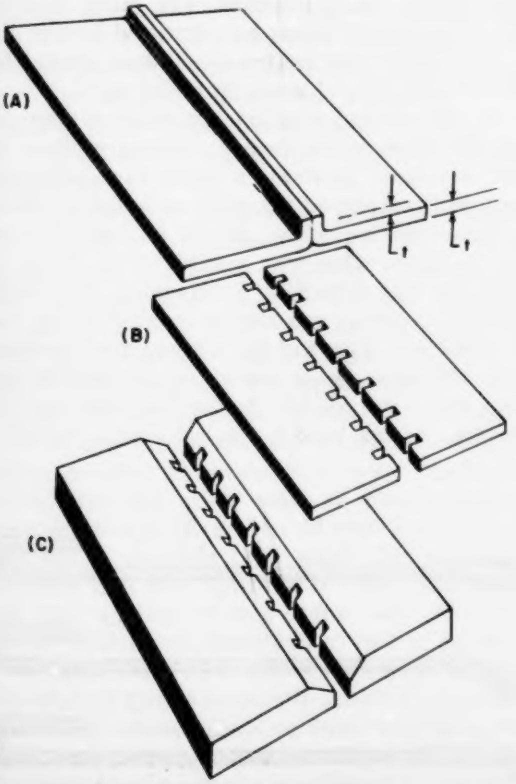


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Figure 8-19.–Edge preparation for gas welding aluminum.

Unbeveled butt welds may be made on thicknesses from 0.062 to 0.188 inch, but in these applications it is necessary to notch the edges with a saw or cold chisel in a manner similar to that shown in (B) of Figure 8-19. Edge notching is recommended in aluminum welding because it aids in getting full penetration and also prevents local distortion. All butt welds in material over 0.125 inch thick are generally notched in some manner.

In welding aluminum over 0.188 inch thick, bevel the edges and notch them as shown in (C) of Figure 8-19. The included angle of bevel may be from 90 to 120 degrees.

After the edges of the pieces have been properly prepared, the surfaces to be welded should be cleaned. If heavy oxide is present on the metal surface, it may be necessary to use a stainless steel wire brush. A solvent-soaked rag will remove dirt, grease, or oil.

Preheating.–Aluminum plate 1/4 inch thick and over should be preheated in order to prevent cracks and to assure more complete penetration. Thin materials should be warmed with the torch prior to welding; even this slight preheat helps to prevent cracks.

Welding Rods.–Two types of welding rods are available for gas welding aluminum alloys; they are the 1100 and 4043 rods. The 1100 rod is used when maximum resistance to corrosion and high ductility are of prime importance. The 1100 rod is used for welding 1100 and 3003 only. The 4043 rod is used for greater strength and to minimize the tendency for cracking. It is used for all other wrought aluminum alloys and may be used for castings.

Welding Fluxes.–The use of the proper flux in welding aluminum is extremely important. Aluminum welding flux is designed to remove the aluminum oxide by chemically combining with it. In gas welding, the oxide forms rapidly in the molten metal. It must be removed or a defective weld will result. To insure proper distribution of the flux, it should be brushed on the surface to be welded and also applied to the welding rod.

Aluminum flux is generally obtained in powder form, and it should conform to Specification MIL-F-6939B. It is best prepared for use by mixing the powder with water to form a paste. The paste should be kept in an aluminum, glass, or earthenware container, since steel or copper containers tend to contaminate the mixture.

It is particularly essential that plenty of flux be applied to the edges of flanged joints since no filler rod is used in these joints. In all cases, the flux should be applied to both the bottom and top sides of the sheet in the area of the weld.

After welding is finished, it is important that all traces of flux be removed by using a stiff bristle brush and hot water. If aluminum flux is left on the weld, it will corrode the metal.

WELDING TECHNIQUE FOR ALUMINUM.–After the pieces to be welded have been properly prepared and fluxed, pass the flame in small circles over the starting point until the flux melts. Then scrape the rod over the surface at about 3- or 4-second intervals, permitting the rod to come clear of the flame each time, otherwise the rod will melt before the parent metal, and it will be difficult to note when the welding should start. The scraping action will reveal when welding can be started without overheating the aluminum. Maintain the same cycle throughout the course of welding except for allowing the rod to remain under the flame long enough to melt the amount of metal needed. The movement of the rod can easily be mastered with practice.

Forehand welding is generally considered best for the welding of aluminum alloys since the flame points away from the completed weld and thus preheats the edges to be welded. Too rapid melting is also prevented. Hold the torch at a low angle when welding thin material (less than 30 degrees above horizontal). For thicknesses 0.188 inch and above, increase the angle of the torch to nearer vertical. Changing the angle of the torch in accordance with the thickness of the metal minimizes the possibility of burning through the sheet during welding.

In welding aluminum alloys up to 0.188 inch thick, there is little need to impart any motion to the torch other than moving it forward. On flanged material, care must be taken to break the oxide film as the flange melts down. This may be accomplished by stirring the melted flange with a puddling rod, illustrated in Figure 8-20. (A puddling rod is essentially a paddle flattened and shaped from a 1/4-inch stainless steel welding rod.)

With aluminum alloys above 0.188 inch in thickness, the torch should be given a more uniform lateral motion to distribute the weld metal over the entire width of the weld. A slight back-and-forth motion will assist the flux in its removal of oxides. Dip the rod in the weld puddle periodically and withdraw it from the puddle with a forward motion.

The angle of the torch has much to do with welding speed. Instead of lifting the flame from time to time in order to avoid melting holes in the metal, it will be found advantageous to hold the torch at a flatter angle to the work. The speed of welding should be increased as the edge of the sheet is approached. The inner cone of the flame should never be permitted to come in contact with the molten metal, but should be held about 1/8 inch away from the metal.

In the vertical position, the torch is given an up-and-down rather than a rotating motion. In the overhead position, a light back-and-forth motion is employed the same as in flat welding.

Heat-treatable alloys should be held in a jig for welding, whenever possible. This helps to eliminate the possibility of cracking. The likelihood of cracking can also be reduced by the use of 4043 rod. This rod has a lower melting range than the alloy being joined and so permits the base metal to solidify before the weld puddle freezes. As the weld is the last area to solidify,

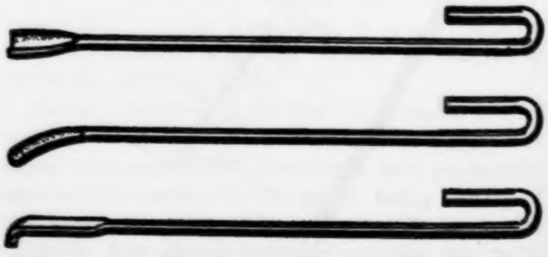

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Figure 8-20.–Puddling rods.

all the contraction strains will be in the weld bead rather than throughout the base metal.

Cracking may also be reduced by tack welding the parts while they are in the jig and then loosening the clamps before completing the seam.

As soon as the weld is completed and the work has had time to cool, it should be washed thoroughly by vigorous scrubbing with a stiff bristle brush and hot running water to remove all traces of flux. If left on the weld, it will corrode the metal. A diluted solution of 10 percent sulfuric acid may be used if hot water is not available. The acid solution should be washed off with cold fresh water after using.

Magnesium Alloys

Gas welding was once a widely used method of joining magnesium alloys; but because of corrosion difficulties caused by flux, its principal use at present is for emergency repair work or for welding on extremely thin gage sheet. Magnesium alloy parts used as structural members on aircraft cannot be repaired by gas welding since these parts are heat treated and it is impossible to regain the required strength after welding.

Nonstructural magnesium parts which have been broken or cracked usually can be sufficiently repaired by gas welding to enable the part to be placed back in service. Generally speaking, such a repair should be considered only as a temporary measure until a replacement part can be obtained. This is particularly true in the case of repairs made on magnesium castings.

The emergency welding of magnesium parts often requires deviation from good practice in order that the parts may be placed back in service quickly. Examples of such deviation are the use of multiple bead welds, the welding of sections that are impossible to clean thoroughly, the gas welding of cast metal, and the inadequate cleaning of welds due to lack of facilities.

Because the flux is very corrosive, gas welding is restricted almost entirely to simple butt and corner welds where complete flux removal is possible after welding. For this reason, gas welding has been almost entirely supplanted by the inert-gas shielded arc welding process discussed in chapter 10. However, gas welding does possess the advantages of less-fit up and jigging requirements, and can be done by less highly skilled operators than inert-gas arc welding requires.

The strength properties of gas welds in magnesium sheet are usually lower than those of inert-gas arc welds. Corrosion resistance of gas welds equals that of inert-gas arc welds, provided all traces of flux have been removed.

Welding fluxes for magnesium are supplied in dry powder form in glass jars which must be kept tightly closed when not in use. It is made into a paste by mixing one part water to two parts of flux. Only enough flux paste for one day's use is mixed at one time and the paste, too, is kept in covered glass containers when not being used.

PREPARATION OF MAGNESIUM FOR WELDING.–Sheet magnesium alloy up to 0.040 inch in thickness should be flanged by about 3/32 inch to the angle as indicated in Figure 8-21. Butt joints on metal from 0.040 to 0.125 inch in thickness are neither flanged nor beveled, but a space of 1/16 inch should be allowed between the edges of the joint. For butt joints in metal thicker than 0.125 inch, bevel down each edge 45 degrees to make a 90-degree included angle for the V. Allow 1/16 inch space between the edges of the joint for metal 0.125 to 0.250 inch thick and 1/8 inch space for metal 0.250 inch and up. (See Fig. 8-21.)

Remove oil or grease with a suitable solvent. Select a filler rod of the same material as the base metal. The filler rod and both sides of the seam should be covered with flux. A neutral or

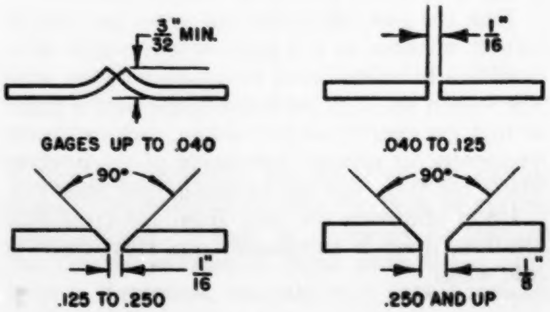

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Figure 8-21.–Preparation of edges for welding magnesium sheet.

slightly carburizing flame should be used, and it should be held at a flat angle to the work to avoid burning through.

WELDING TECHNIQUE FOR MAGNESIUM.–Start the weld by tacking the seam at intervals of 1/2 to 1 1/2 inches. If the sheet warps while tack welding, it can be straightened with a wooden or plastic mallet.

After tack welding, coat the tacks with flux and then weld completely a piece of the seam from 1 to 2 inches long at each end. This reduces the tendency of the metal to warp while the weld is being made. Shrink cracks at the end of the seam can be eliminated by adding an excess of weld metal at that point. Use as little heat as possible.

Each of the two major producers of magnesium recommends a different technique for welding magnesium. One prefers keeping the filler rod in the molten pool of metal, which means getting enough flux on the rod before starting the weld so that the rod will not be taken out of the puddle to renew the flux. The other producer recommends the same torch and rod technique for magnesium as used for aluminum. Use the method with which you can attain the greater success.

If any part of the weld begins to oxidize, carefully scrape out the oxidized portion of the weld before continuing the operation.

Upon completing the weld, let it cool slowly. When cool enough to handle, scrub the accessible parts lightly to remove most of the flux. Then put the part in hot water and soak off the large particles of flux adhering to any inner parts of the weld which scrubbing does not affect.

Take the part out of the hot water and soak it for 10 minutes in a 1 percent citric-acid solution. Gas bubbling from the vicinity of the weld will loosen the flux particles. If the part is made so that gas cannot escape readily, rock or turn it frequently to prevent formation of gas pockets where the flux may not be completely removed.

Upon removing the part from the citric-acid solution, drain it thoroughly and rinse clean in cold water.

CUTTING FERROUS METALS

There are numerous everyday uses for oxyacetylene flame cutting. It is a quick, inexpensive way to cut iron or steel where the effect of burning or heating the edge of a piece of metal is not objectionable.

Ferrous metals combine with oxygen so readily that the oxygen in the air can start the reaction, as rusty pieces of iron in scrap piles will attest. The rust is iron oxide, and the longer a piece is exposed to the elements, the more it is worn away and the more rust it collects.

Cutting iron or steel with an oxyacetylene torch is simply a speeding up of this process in a localized area, because iron oxidizes much more readily when it is hot. Pure oxygen, if directed on a hot piece of iron, increases the rate of oxidation so enormously that the metal is actually burned away.

The metal is heated to a bright red (1,400° to 1,600°F), which is the kindling or ignition temperature, and a jet of high-pressure oxygen is directed against it. This oxygen blast combines with the hot metal and forms an intensely hot oxide. The molten oxide is blown down the sides of the cut, heating the metal in its path to a kindling temperature. The metal thus heated also burns to an oxide which is blown away on the underside of the piece. This action is precisely that which the torch accomplishes when the mixing head is replaced with a cutting attachment or when a special cutting torch is used.

Figure 8-22 shows an example of a cutting torch. It has the conventional oxygen and acetylene needle valves, which control the flow of the two gases. Many cutting torches have two oxygen needle valves so a finer adjustment of the neutral flame can be obtained.

A cutting torch combines a heating flame with a jet of pure oxygen under pressure. The heating flame preheats the metal to a bright red, and the oxygen jet is directed upon the hot metal to burn it away and thus form a slit, known as a kerf, in the metal.

The heating flame in a cutting tip is generally not fed by a single hole as in a welding tip, but instead comes through several holes which are arranged in a ring around a larger central hole for oxygen. (See Fig. 8-22.) The central oxygen tube tapers as it reaches the tip opening to increase the velocity.

The high-pressure cutting oxygen jet is regulated by an auxiliary oxygen control valve

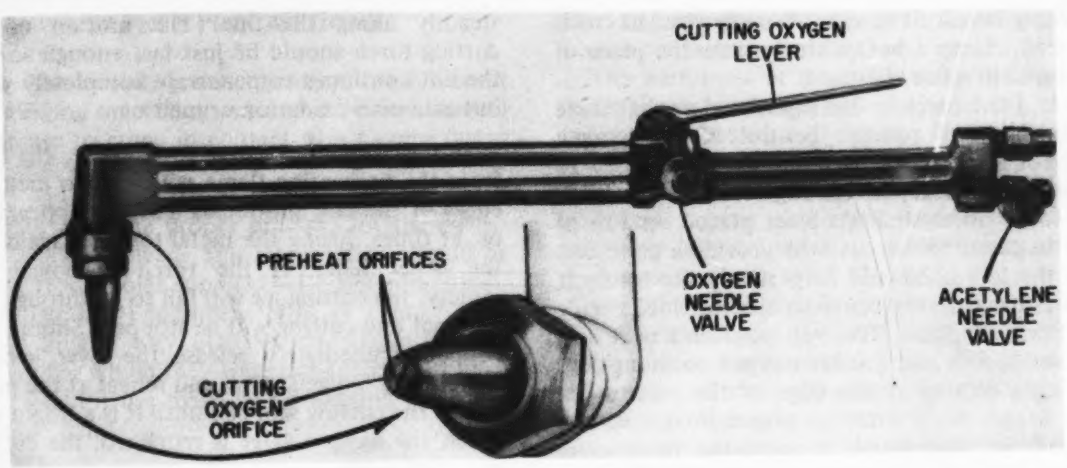

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Figure 8-22.–Cutting torch

generally operated by a lever. This is shown in Figure 8-22.

Four different size tips are generally supplied for cutting metals of varying thicknesses. There are also special tips for cleaning metal; cutting rusty, scaly, or painted surfaces; rivet cutting; and other special jobs.

In cutting, as in welding, the pressure of oxygen and acetylene and the size of tip are determined by the thickness and quality of the metal to be cut. Table 8-3 shows the approximate pressures for various size tips.

Table 8-3.–Approximate pressure for various tip sizes

Tip No.	Thickness of metal (inches)	Acetylene pressure (pounds)	Oxygen pressure (pounds)
1	1/8	4	10
1	1/4	4	15
1	3/8	4	20
1	1/2	4	25
2	3/4	5	30
2	1	5	40
2	1 1/2	5	50
2	2	5	60
3	3	6	70
3	4	6	80
3	5	6	90
4	6	7	100
4	8	7	130
4	10	8	160

CUTTING PROCEDURE

Before beginning a cutting operation with an oxyacetylene cutting torch, a thorough inspection of the area should be made. There should be no combustible material which could be ignited by the sparks and slag produced by the cutting operation.

Insert the proper size tip in the cutting torch. Next, adjust the oxygen and acetylene pressures for the thickness of material to be cut. (The tip size and pressures should be in accordance with the cutting torch manufacturer's recommendations.) Put on goggles and gloves, then light the torch.

To light the torch, turn on the acetylene needle valve, light the gas, and adjust the flame to neutral as in welding. When the neutral flame is burning smoothly, actuation of the cutting oxygen control will disclose the type of cutting flame created. It may be necessary to readjust the neutral preheating flame while the control lever is depressed, to make sure that it remains neutral while cutting.

The line to be cut should be marked on the metal with soapstone or chalk. Then place the metal so that this line is beyond the end of the welding bench. If an exceptionally straight cut is desired, clamp a bar of steel across the piece of material to guide the torch.

Hold the torch in the right hand so that there is instant and positive control of the oxygen control lever. The left hand should be used to steady and guide the cutting torch. A fire brick or some other similar object placed on top of the material to be cut will provide a good rest for the left hand and help steady the torch. If the cutting tip wavers from side to side, a wide kerf will be made. This will result in a wide cut, slower speed, and greater oxygen consumption.

Begin cutting at the edge of the piece. (See Fig. 8-23.) Hold the tip perpendicular to the surface of the metal, keeping the inner cone about 1/16 inch from the line. Hold the flame at this point until a spot in the metal turns bright red, then gradually depress the oxygen control lever. As soon as the cutting starts, there will be a shower of sparks from the lower side of the material and the oxygen control level should then be fully depressed.

When the cut has been started all the way through the material, move the torch slowly but steadily along the line. The motion of the cutting torch should be just fast enough so that the cut continues to penetrate completely without excessive oxidation or melting.

If the torch is moved too slowly, the heat from the preheating flame will tend to melt the edges of the cut, producing a ragged appearance or, at times, fusing the metal together again. On the other hand, if the torch is moved too rapidly, the cutting jet will fail to go through the material and cutting will be stopped. Should this happen, immediately release the lever, closing the cutting oxygen valve, and reheat at the point where the cutting stopped until it is a bright red. When the oxygen valve is reopened, the cutting will start again.

When the cut is finished, the cut section may stick to the main piece. This means that some of the slag produced by the cutting action has bridged across the bottom of the two pieces and on cooling has formed a thin crust which holds them together. The crust is quite brittle, however, and a smart blow from a hammer will break it and separate the pieces.

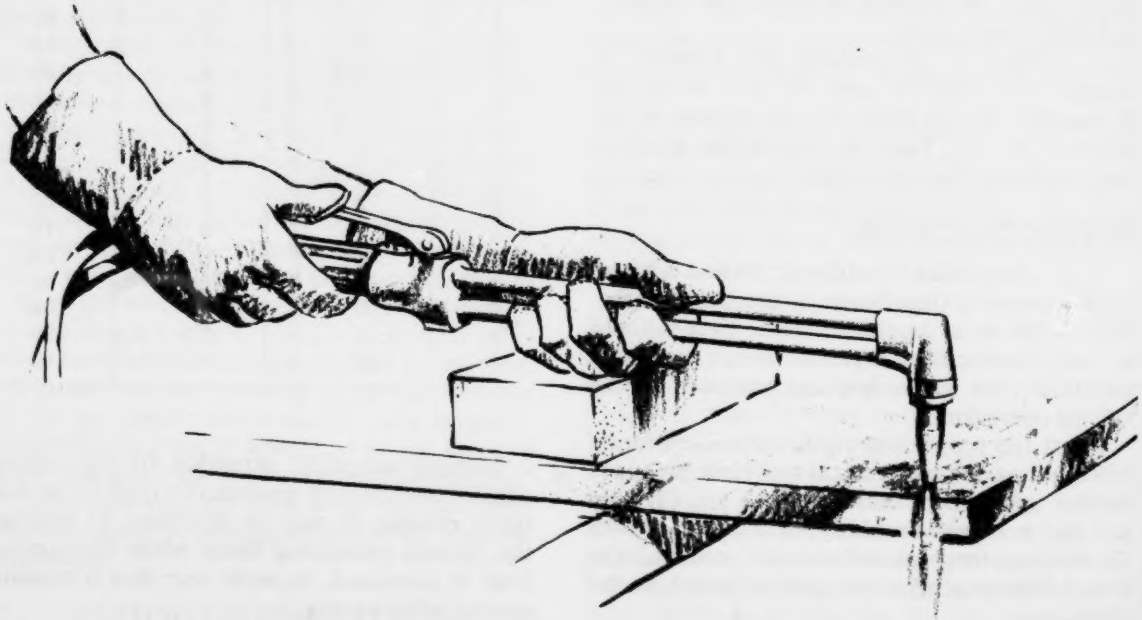
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Figure 8-23.—Starting the cut.

SAFETY PRECAUTIONS

1. Use no oil, grease, or any other lubricant on welding or cutting apparatus. Never allow oil or grease to come in contact with oxygen under pressure.
2. Always use the proper tip or nozzle, and operate it at the proper pressure for the particular work involved. This information should be taken from tables supplied with the equipment.
3. Do not experiment with or change regulators in any way. Always use regulators with the gas for which they were designed.
4. Do not use matches for lighting torches; a serious hand injury may result. Use friction lighters.
5. Do not light torches from hot metal, especially in a confined space. An explosive mixture of acetylene and oxygen in a confined space may cause damage or personal injury when ignited. Do not allow such a mixture to accumulate.
6. Always wear goggles when working with a lighted torch. Use only goggles designed specifically for welding use.
7. When extinguishing the torch, close the acetylene valve first, then close the oxygen valve.

BRAZING

Originally, brazing meant joining with brass, or "brassing." As the process was improved and new joining alloys were developed, the term assumed its present meaning–a group of thermal joining processes in which the bonding material is a nonferrous metal or alloy with a melting point higher than 800°F, but less than the metals being joined. Brazing, therefore, includes silver soldering, bronze welding, and hard soldering.

Brazing requires less heat than welding, and therefore may be used to join metals that are injured by high heat. The strength of brazed joints is not so great as welded joints however, and, for this reason, brazing is not used for critical structural repairs on aircraft.

As the definition of brazing implies, the base metal parts are not melted. The brazing metal adheres to the base metal by molecular attraction and intergranular penetration; it does not fuse and amalgamate with them.

The usefulness of brazing is easily recognized when the many metals that can be joined by this process are considered. Brazing is applicable to the joining of cast iron, malleable iron, carbon steels, alloy steels, wrought iron, galvanized iron and steel, copper, and brass, bronze, and nickel alloys. It is also used to join dissimilar metals, such as cast iron to steel, or steel to copper.

Its principal use is in maintenance, making and repairing tools, jigs, and machinery. In this field it has many applications and attendant advantages. Among these are the relatively low temperatures involved, reduced chance of an excessively annealed area near the brazed joint, and the ability of a properly prepared brazed joint to stand heavy compression and impact loads.

BRAZING TECHNIQUE

In brazing a joint, first bevel down the edges as in welding steel. Clean the surrounding surfaces of dirt, rust, and so forth, then select the proper brazing alloy for the job.

The Navy supplies four brazing alloys which are graded A, B, C, and D. Grades A and B, with melting points of about 1,600°F, are used for strong connections on steel, cast iron, brass, bronze, and general brazing of nickel alloys. Grades C and D are suitable for brazing steel parts that are to be subjected to heat treatment under 1,600°F, after brazing. The melting point of grade C varies from 1,650° to 1,760°F, and that of grade D from 1,725° to 1,825°F.

Because of its higher melting point, grade D brazing alloy is more difficult to apply than grade C but is preferable with chrome-vanadium and chrome-molybdenum steel. When selecting a brazing alloy, choose one whose melting point is at least 100°F less than the metal being joined.

A brazing flux is necessary to obtain a good union between the base metal and the filler metal. A good flux for brazing steel is a mixture containing two parts borax and one part boric acid. Use a neutral torch flame and move it with a slight, semicircular motion.

Preheat the base metal slowly with a mild flame, and when it reaches a dull red heat (in the case of steel), heat the rod to a dark or purple color and dip it into the flux. Enough flux adheres to the rod and it is not necessary to spread it over the surface of the metal.

Bring the filler rod near the tip of the torch and let the molten bronze flow over a small area of the seam. The base metal must be at the flowing temperature of the filler metal before it will flow into the joint. The brazing metal melts when applied to the steel and runs into the joint by capillary attraction. Continue adding the rod, as the braze progresses, with a rhythmic dipping action so that the bead will be built to a uniform width and height. Complete the job rapidly and with as few passes of the rod and torch as possible.

The ideal brazing job is completed in one pass. Avoid multiple layers, and if the job requires more than one pass, always remove and replace the spent flux before applying succeeding layers of filler metal.

It is important that the brazing temperature be carefully controlled. If the base metal is heated excessively above the flow temperature of the brazing alloy, the bronze will boil when added and the low melting point alloys of the bronze will burn out, leaving the bronze porous and brittle. On the other hand, if the base metal is not hot enough, the bronze will not flow smoothly, but will form elusive drops which roll off as fast as the bronze is applied.

After finishing the job, allow it to cool slowly.

BRAZING CAST IRON TO STEEL

To braze cast iron to steel, flow molten bronze from a filler rod over the hot surface of the metal to be joined to obtain a solid bond between the edges of the seam.

Heat the work to be joined to a temperature slightly above the flow point of the brazing alloy. In the case of steel, this point is determined when the metal reaches a dull red color. Metals which lose their original qualities when melted can thus be joined by brazing without undergoing loss of those qualities.

Brazing is usually the best method of joining unlike metals (copper and steel) or two like pieces of a metal such as malleable cast iron which has been heat-treated.

Since the base metal is not melted in brazing, the joining process is greatly simplified. The preheating necessary in fusion welding is largely eliminated.

In deciding whether brazing of a joint is justified, remember that a metal which will be subjected to a sustained high temperature in use should not be brazed.

BRAZING BRASS

Brazing, rather than welding, is the most effective method of joining brass, because such technique requires a filler rod with a melting point slightly lower than the base metal. Thus, melting of the base metal is eliminated.

Brass, in its simplest form, is an alloy of copper and zinc, although other metallic elements are often added to improve its characteristics.

Naval brass, one of the best of these alloys, consists of 62 percent copper, 0.5 to 1.5 percent tin, 0 to 0.10 percent iron, 0.20 percent lead, and the remainder zinc. Its three advantages are high strength, toughness, and resistance to corrosion. It comes in bar, plate, rod, sheet, and strip form, and in soft, half-hard, and hard condition.

Brass has few uses in aircraft, other than in pipe fittings, and, consequently most of the brazing will be in connection with general repair work on shop equipment, not on aircraft.

The torch flame with brass should have a slight excess of oxygen—one of the very few instances where an oxidizing torch flame is used. Be especially careful in applying heat to brass to avoid burning or oxidizing the zinc content of the brass.

Any good commercial brazing and welding flux will do for this operation, or, in an emergency, borax diluted with boric acid or sodium carbonate may be used. Apply the flux by dipping the hot end of the filler rod in the mixture or by painting the dissolved flux on the rod. Flux protects the hot metal from the air and other gases by forming a film over it, and also cleans the hot brass of oxides formed during the welding process.

The filler rod for brass should have approximately the same composition as the base metal. As pointed out earlier, a rod with a slightly lower melting point than the base metal gives the best results. Use either a grade A or B rod for this job. Two commercial filler rods which are also good are Tobin bronze and manganese bronze rods.

The joints used in brazing brass are the same as those used in welding.

Be sure to clean the surface with a file or abrasive cloth, and allow for expansion and contraction. Thick pieces of brass must be beveled by filing or by some other mechanical method. Never bevel brass by melting or cutting since this method destroys the zinc in the brass. To reduce the amount of heat required for the actual brazing and lessen the danger of warping, preheat heavy brass parts.

SILVER SOLDERING

Silver soldering is one of the several methods of brazing. The principal use of silver solder is the fabrication of high pressure oxygen lines, and other parts which must withstand vibration and high temperatures. Silver solder is used extensively to join copper and its alloys, nickel, and silver, as well as various combinations of these metals, and thin steel parts.

Silver solder can be obtained in several different grades with silver content ranging from 14.5 to 66 percent, and melting points varying from 1,160° to 1,430°F. The standard forms of silver solder are strips and wires, but it is also made in rod form.

If the job to be performed is one in which the solder may be placed in the joint before applying heat, use the strip form. For joints requiring the solder to be applied after heating, use the wire form.

It is necessary to use flux in all silver soldering operations because of the necessity for having the base metal chemically clean without the slightest film of oxide to prevent the silver solder from coming into intimate contact with the base metal.

A paste flux is used generally in most silver soldering. If a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid is satisfactory for high-melting-point silver solder. Prepared flux begins to melt at 800°F, becomes fluid at 1,100°, and remains stable up to 1,600°F. It melts at a slightly lower temperature than the solder.

The joint must be physically clean, which means free of all dirt, grease, oil and paint, and also chemically clean–minus all traces of oxide film. After removing the dirt, grease, and paint, remove any oxide which may be present by grinding or filing the piece until bright metal may be seen. During the soldering operation, the flux continues the process of keeping oxide away from the metal.

Joints to be silver soldered must have smooth edges and must fit tightly together. Only a film of silver solder is usually needed for a sound joint. Strength is not added to the joint and expensive solder is wasted if it is used as filler metal.

In Figure 8-24 are presented three recommended types of joints for silver soldering. Flanged, lap, and edge joints, in which the metal may be formed to furnish a seam wider than the base metal thickness, furnish the type of joint which will bear up under all kinds of loads. If a lap joint is used, figure the amount of lap according to the strength needed in the joint. Here is a handy rule of thumb: For strength equal to that of the base metal in the heated zone, the amount of lap should be four to six times the metal thickness for sheet metal and small diameter tubing.

The oxyacetylene flame for silver soldering should be neutral, but may have a slight excess of acetylene. It must be soft, not harsh. During both preheating and application of the solder, hold the tip of the inner cone of the flame about one-half inch from the work. Keep the flame moving so that the metal will not be overheated.

If the piece is large, preheat a considerable area around the joint before applying the solder, especially if the base metal conducts heat rapidly. When soldering two pieces which have different thicknesses, or which conduct heat with unequal speed, gage the preheating so that both parts reach the soldering temperature at the same time.

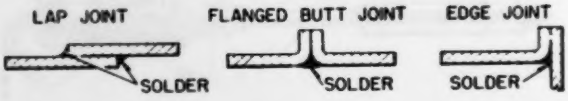

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Figure 8-24.—Recommended joints for silver soldering.

When both parts of the base metal are at the right temperature (indicated by the flow of flux), begin applying solder to the surface of the under or inner part at the edge of the seam. It is necessary to simultaneously direct the flame over the seam and keep moving it so that the base metal remains at an even temperature.

SOFT SOLDERING

Soft soldering is used chiefly for copper, brass, and coated iron in combination with mechanical seams–that is, seams that are riveted, bolted, or folded. It is also used where a leakproof joint is desired, and sometimes for fitting joints to promote rigidity and prevent corrosion. Soft soldering is generally performed only in very minor repair jobs. This process is also used to seal electrical connections. It forms a strong union with low electrical resistance.

Soft solder yields gradually under a steadily applied load and should not be used unless the loads transmitted are very low. It should never be used as the sole means of attachment of two structural members.

SOLDERING COPPER

A soldering copper (called a soldering iron if it is electrically heated) is the tool used in soldering. Its purpose is to act as a source of heat for the soldering operation. The bit, or working face, is made from copper, since this metal will readily take on heat and transmit it to the work.

The bit should be relatively blunt. If it is too thin and pointed, it will cool too rapidly. Figure 8-25 shows a correctly shaped bit.

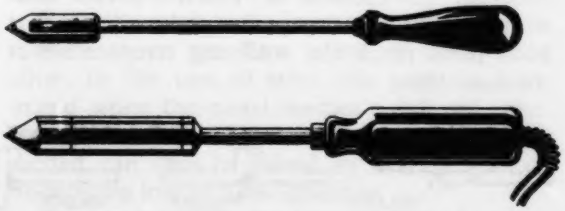

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Figure 8-25.–Soldering copper and soldering iron.

Soldering coppers may be heated by blowtorch or a gas flame. Electric soldering irons have an internal heating element and are especially useful where a constant heat is required, as in soldering electrical connections.

TINNING THE COPPER

To tin the copper, first heat it to a bright red, then clean the point by filing until it is smooth and bright. No dirt or pits should remain on its surface. After the copper has been mechanically cleaned, it should be reheated sufficiently to melt solder, and chemically cleaned by rubbing it lightly on a block of sal ammoniac. (If sal ammoniac is not available, powdered resin may be used.) Then apply solder to the point and wipe with a clean, dry or damp cloth.

NOTE: When heating the soldering copper, the heating flame should not be directed on the point as it will form an oxide and prevent good tinning.

The last two operations may be combined by melting a few drops of solder on a block of sal ammoniac (cleaning compound) and then rubbing the soldering copper over the block until the tip is well coated with solder. A properly tinned copper has a thin unbroken film of solder over the entire surface of its point.

If the point of the copper needs reshaping, it should be done by forging. In performing this step, remove all of the oxides and reheat the copper to a bright red. Using a heavy hammer, forge the point to the desired shape on an anvil, then tip in the usual manner.

When using the copper, occasionally dip the point in a solution of one part of sal ammoniac to 30 parts of water. (Keep this solution in an earthenware jar.) If sal ammoniac is not available, powdered resin will serve to tin the point.

The fluxes ordinarily used for soft soldering are solutions or pastes containing zinc chloride. The liquid or paste medium holding the flux material is evaporated by the heat of the soldering operation, leaving a layer of flux on the work. At the soldering temperature, the flux is melted and practically decomposed with the liberation of hydrochloric acid. This acid then dissolves the oxides from the solder and the work. The melted flux also forms a protective film on the work, preventing further oxidation.

Zinc chloride flux is used on iron, copper, brass, and galvanized iron. Muriatic acid is often used in its raw state as a flux for soldering galvanized iron and zinc.

Because zinc chloride fluxes have a corrosive action, it is necessary to employ a noncorrosive flux for work on electrical connections or other places where all traces of flux cannot be removed. Resin, either in powder or paste form, is the most commonly used flux of this type.

Use a noncorrosive commercial flux or a resin flux for electrical connections or where it is impossible to remove all traces of flux from the work. Zinc chloride and other corrosive fluxes must be washed from the work to prevent corrosion.

TYPES OF SOFT SOLDER

Soft solders are chiefly alloys of tin and lead. The percentages of tin and lead vary considerably in various solders, with a corresponding change in their melting points, ranging from 293° to 592°F. "Half-and-half" (50-50) solder is a general-purpose solder and is most frequently used. It contains equal proportions of tin and lead and melts at approximately 360°F.

Soft solders are usually supplied in bar or wire form, although they can also be obtained in pig or granulated form for jobs requiring large quantities of solder. Some wire-shaped solders have a core of flux. The most popular solder of this type has a core of resin and is used chiefly on electrical connections.

The film of solder between the surfaces of a joint must be kept thin to make the strongest joint.

SOLDERING TECHNIQUE

The application of the melted solder requires somewhat more care than is apparent. The parts should be locked together or held mechanically or manually while tacking, as shown in Figure 8-26. To tack the seam, touch the hot copper to a bar of solder, then use the drops of solder adhering to the copper to tack the seam at a number of points.

Hold a hot, well-tinned soldering copper so that its point lies flat on the metal at the seam, while the back of the copper extends over the seam proper at a 45-degree angle, and touch a bar of solder to the point. As the solder melts, draw the copper slowly along the seam as in Figure 8-27. Add as much solder as necessary without raising the soldering copper from the job. The melted solder should run between the surfaces of the two sheets and cover the full width of the seam. Work along the seam only as fast as the solder will flow into the joint. When

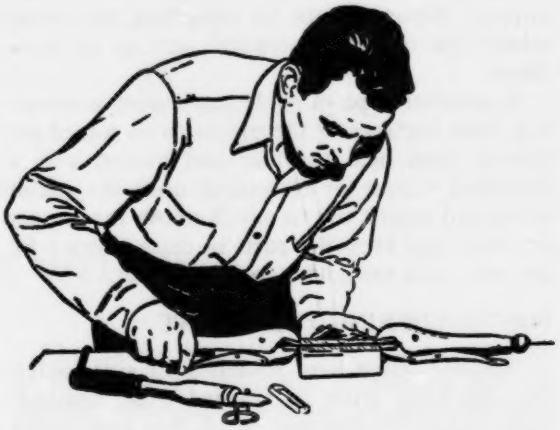
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Figure 8-26.–Holding the parts together.

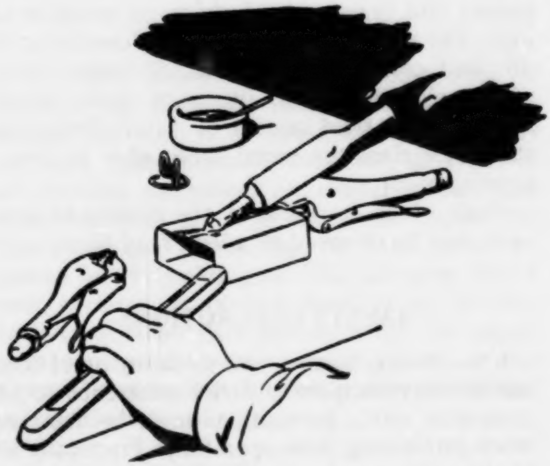
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Figure 8-27.–Soldering a seam.

the copper cools, reheat it or take another hot copper. Resume work by remelting the solder where the operation stopped, and go on from there.

In another type of soldering known as sweating, both surfaces of the pieces to be joined are tinned, then held together and heated with a soldering copper or blowtorch until the solder melts and begins to run out. Remove the copper or torch and keep the parts in close contact by pressure until the solder cools and sets.

POST-SOLDERING TREATMENT

Whether doing hard soldering or soft soldering, the joint must be cleaned when finished. This means the removal of all flux that might cause corrosion or prevent paint from adhering. In some cases, the joint is immersed in a "bright dip" to restore the color.

If the base metal is nonferrous–that is, not made from iron ore–a good solution for removing flux consists of 1 fluid ounce sulfuric acid, 1.5 ounce sodium bichromate, and 1 gallon of water.

Boil ferrous metals in a 10 to 15 percent solution of caustic soda for 30 minutes to eliminate the flux. In either case, rinse the metal thoroughly in clean water after treating it.

The job may require that metal which has been discolored by heat, in the soldering process, be restored to its original color. The color of copper and brass particularly seems sensitive to heat. The remedy is a "bright dip" consisting of 68 fluid ounces sulfuric acid, 20 fluid ounces nitric acid, 0.12 fluid ounce of hydrochloric acid, and 40 fluid ounces of water. Following this bath, rinse the metal thoroughly in clean, running water.

Scale which is caused by the heating of steel parts may be removed by a light sand blast.

SAFETY PRECAUTIONS

Gas welding, brazing, and soldering operations can be very dangerous. Strict adherence to all applicable safety precautions must be observed when performing these operations. Practically all of the welding and cutting operations performed by the AMS are conducted in specifically designated locations. If welding or cutting is to be done in any other location, approval of the job and the precautions to be taken must be obtained from higher authority.

Some of the common hazards encountered and the precautions to be followed when operating welding equipment and/or supervising a welding shop are as follows:

1. Use only approved apparatus, such as torches, regulators, hose, valves, and accessories that have been examined, tested, and found to be safeguarded in accordance with accepted standards.
2. Only qualified operators are allowed to perform welding, brazing, and soldering operations. NOTE: This does not preclude on-the-job training of nonqualified personnel if supervised by a qualified operator.
3. While the equipment is in use, it must be frequently inspected for evidence of leaks in the hose, couplings, valve stems, or other points of the system. Otherwise, an explosive mixture of gas and air may accumulate with serious results.
4. Positive ventilation of the welding shop/area must be provided and maintained during all welding, cutting, or heating operations to prevent suffocation, fire, and explosion due to gas leaks; heat prostration, and/or illnesses such as metal fume fever or metal poisoning caused by breathing toxic vapors which may be formed under certain conditions.
5. If all fire hazards cannot be removed from the area of welding operations, fire watches must be properly instructed and posted in the vicinity.
6. Suitable fire-extinguishing equipment of approved types must be maintained near all welding and/or cutting operations.
7. Protective clothing must be provided and worn at all times when welding and/or cutting operations are being performed.
8. Not only welding and cutting operators, but also other personnel such as helpers, inspectors, etc., who remain in the vicinity, must use suitable helmets, hand-held shields, or goggles during all welding/cutting operation, in order to protect their eyes from stray flashes, reflected glare, and flying particles.
9. After welding/cutting operations are completed, the operator should mark the hot metal or provide some other means of warning other workers who may inadvertently come in contact with the hot metal.

CHAPTER 9

ELECTRIC ARC WELDING

Electric arc welding processes include manual shielded metal arc welding and gas shielded metal arc welding. Manual shielded metal arc is discussed in this chapter. Gas shielded metal arc is discussed in chapter 10.

In order to understand the operation of electrical welding equipment, you must have a basic understanding of electricity. In particular, you must be entirely familiar with the terms used to describe electrical equipment and with the units of measurement used in connection with electricity. If you do not understand the terms or units of measurement used in this chapter, study the applicable parts of the Rate Training Manual, Basic Electricity, NavPers 10086-B.

Manual shielded metal arc welding is a fusion process based on the principle of generating heat with an electric arc jumping an airgap to complete an electrical circuit. This process develops considerably more heat than an oxyacetylene flame. In some applications it reaches a temperature of approximately 10,000°F.

The welding circuit consists of a welding machine, two leads, an electrode holder, an electrode, and the work to be welded. The electrode, which is held in the electrode holder, is connected to one lead, and the work to be welded is connected to the other lead. When the electrode is touched to the metal to be welded, the electrical circuit is completed and the current flows. When the electrode is withdrawn from the metal, an airgap is formed between the metal and the electrode. If this gap is of the proper length, the electric current will bridge this gap to form a sustained electric spark, called the electric arc.

The instant the arc is formed, the temperature of the work at the point of welding and the welding electrode increases to approximately 6,500°F. This tremendous heat is concentrated at the point of welding and in the end of the electrode, and simultaneously melts the end of the electrode and a small part of the work to form a small pool of molten metal commonly called the crater.

Under the intense heat developed by the arc, a small part of the work to be welded is brought to the welding point almost instantaneously, and tiny particles of molten metal are formed at the end of the electrode. These tiny particles, or globules, are then forced across the arc and deposited in the molten crater in the work. The decomposition of the electrode covering shields the molten metal from oxidation.

WELDING EQUIPMENT

A wide variety of welding equipment is available and there are many differences in the makes and models of equipment produced by different manufacturers. However, all types of arc welding equipment are similar in that their basic function is to produce and handle the high-amperage, low-voltage electrical power required for the welding arc. The following discussion pertains to typical items of arc welding equipment rather than specific items. The appropriate manufacturer's instructions manual should be consulted for information pertaining to specific items of equipment.

WELDING MACHINES

The function of the welding machine is to supply and control the current for arc welding.

The means of supplying current of the appropriate voltage is provided by a motor generator or a transformer. Controlling and adjusting the arc length (necessary for the work to be accomplished) is provided by switches and selectors on the welding machine. Provisions for attaching two cables are provided on the welding machine. The ground cable is attached to the ground cable connector on the machine, and the other end is attached to a ground plate or clamp which is attached to the work.

The welding cable is attached to the welding cable connector on the machine, and the other end is attached to the electrode holder. Figure 9-1 shows a typical arc welding circuit.

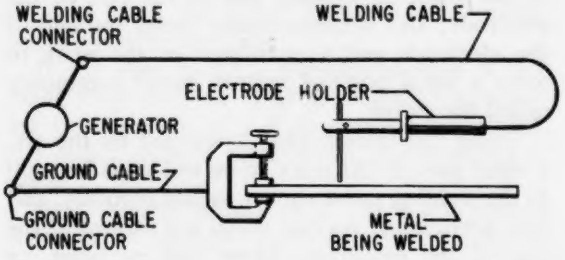

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Figure 9-1.—Typical welding circuit.

Arc welding machines are classed as either direct-current (d-c) type welding machines or alternating-current (a-c) type welding machines. Each type has its advantages and disadvantages peculiar to the type of current produced. Advantages such as initial cost, portability, and operating expenses are claimed for each class of welding machines. However, from a welder's standpoint, d-c equipment offers fine current adjustments and choice of polarity. An a-c welder eliminates practically all arc blow (which is troublesome to welders using d-c equipment) especially when making heavy fillet or deep groove welds.

Electric arc welding machines are manufactured in sizes ranging from 100 to 600 amperes for manual welding. Machine sizes are based on their amperage output. For example, a 100-ampere machine will deliver 100 or more amperes (the output is rated conservatively by most manufacturers). Naturally, the range in sizes of arc welding machines is governed by the class and range of work for which it is to be used.

The 200-ampere machine is the machine which most economically satisfies the needs of aircraft welding. A machine of this size will rapidly weld the light metals used in aircraft and can also be used for most of the maintenance in the shop. Each type welding machine is discussed separately in the following paragraphs.

Direct-Current (D-C) Welder

A direct-current welder consists of a direct-current generator driven by a suitable type of motive power. The voltagle of such a generator will usually range from 15 to 45 volts across the arc, although any setting is subjected to constant variation due to arc conditions.

A fairly wide range of current output is necessary to accommodate the various kinds of work. The range of current will also vary, depending upon the type unit and work for which it was designed.

In direct-current welders, the generator is of a variable voltage type and so arranged that the voltage automatically adjusts itself to the demands of the arc. However, the open circuit voltage is manually set to the correct range by means of a rheostat mounted on the control panel. Amperage of the welding current is manually adjustable, and is usually set to the proper range by means of a reactance arrangement, or selector switch which taps into the field coils of the generator at different points to increase or decrease its strength. When both voltage and amperage are adjustable by means of individual controls, the machine is referred to as a dual-control type. The dual-control machine is the most popular in use today. Figure 9-2 shows a dual-control direct-current welding machine.

Another system employed to a limited extent makes use of adjustable generator brushes for the control of the current. Machines of this type are provided with one control which proportionately varies both amperage and voltage by the movement of the brush assembly.

When a power supply is available, welding generators are driven by means of an electric motor. The armatures of both generator and motor are usually on a single common shaft.

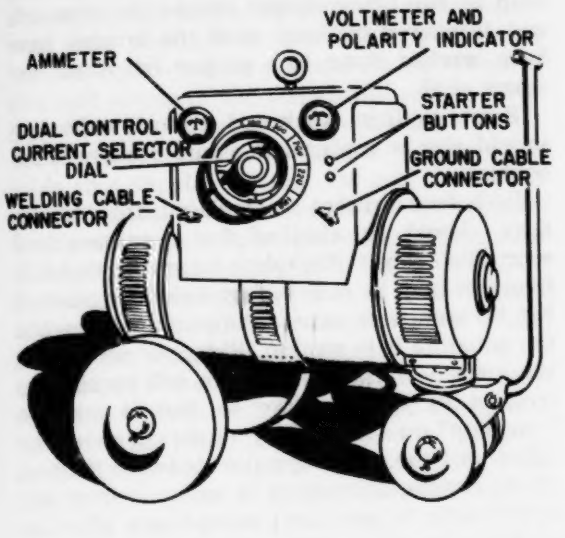

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Figure 9-2.—Dual-control direct-current welding machine.

However, some of the older machines are arranged whereby the motor drives the generator through a flexible coupling.

In many instances, arc welding must be performed in places where a power supply is not available. Portable gasoline-engine-driven generators are particularly adaptable in such cases, as they are available in compact units easily transported from place to place. The engine used for this purpose must be fitted with a suitable governor to compensate for the varying loads imposed by the welder.

Alternating-Current (A-C) Welder

The a-c welding machine illustrated in Figure 9-3 derives its current from a core transformer. The primary coil is connected directly to the power line, and the secondary coil supplies the welding current. Current control, which varies in different models, is accomplished by either a bridge reactor, movable coil, movable core, or by tapping the secondary coil. All means of current control, except the tapped secondary coil method, offer continuous control.

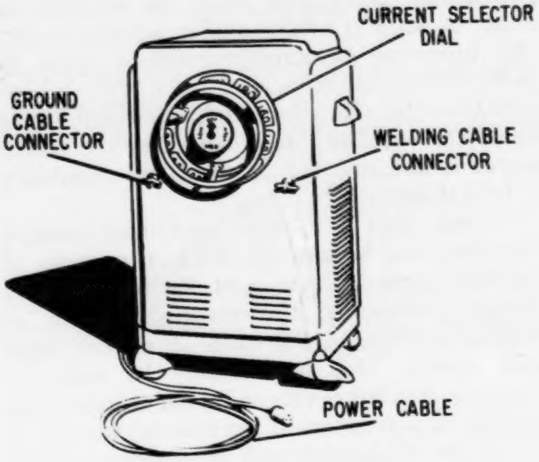

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Figure 9-3.—Transformer type (a-c) welding machine.

The a-c welder has rapidly gained in popularity because of advances in machine design and the development of heavy-coated electrodes especially designed for alternating-current welding.

Rectified (D-C) Welders

This type welder is being used extensively for welding in the Navy and is one of the most recent developments in the field of welding. The d-c rectifier type welder combines the advantages of both d-c and a-c welding without their inherent disadvantages.

The d-c rectifier welding machine combines a three-phase transformer, a three-phase adjustable reactor, and a three-phase, full wave, high voltage plate type rectifier.

The efficiency of the d-c rectifier welder is rated at 66 percent as compared to 54 percent for motor generator welders. In addition to offering economy, it also affords desirable welding characteristics such as extremely rapid responses to changes in current and voltage conditions. The most outstanding advantages for the machine, however, are claimed on its operation where welding is done at low current densities.

Maintenance of Welders

Proper maintenance of welding machines is very important. Because of the dust and grit present in all welding shops, it is necessary to periodically check and clean the machine in order to keep it in the proper working order. The following cleaning instructions apply to most welding machines.

NOTE: Prior to attempting any maintenance inside the machine, make sure that the power source is disconnected to avoid any possibility of fatal shock.

Forced draft is used to cool most welding machines, and because of this fact, particles of dirt are carried throughout the unit. Under average conditions, the machine should be cleaned with dry, compressed air at least once each month. This may readily be done by removing the dust covers and shields. Should the machine appear greasy at the time of cleaning, it should be dismantled and thoroughly washed with safety solvent (Trichlorethane 1, 1, 1). During the regular monthly cleaning, an inspection should be made of the condition of the switch points, brushes, commutator, and bearings.

NOTE: All maintenance performed on the welding machine should be done in accordance with the maintenance instructions manual for the machine concerned.

The machine should be given a thorough greasing at 4- to 6-month intervals. This may follow the cleaning operation and should include all bearings in the unit. Too much grease may be as harmful as not enough, as a surplus may be thrown upon the commutator. Grease on the commutator may result in serious damage or a fire hazard.

To properly grease a bearing of the type used in welding machines, the plug should be removed on the lower side of the bearing boss and the machine started. Grease may then be injected into the fitting until it begins to emerge from the plug hole. Allow the machine to run for several minutes to force out any pressure on the grease, then replace the plug. Only an approved grease should be used.

The brushes and commutators of both the motor and generator are subject to considerable wear. Brushes worn so that spring tension is appreciably reduced must be replaced to maintain proper efficiency of the machine. Although new brushes are formed to fit the commutator, they must often be sanded in to give proper amount of contact. This is done by wrapping a strip of No. 00 sandpaper around the armature and turning it by hand until the brushes have been worked down to a perfect fit. Never use emery cloth.

Brush springs weakened from overheating should also be replaced to assure positive brush contact.

Each time brushes are replaced, the commutator should be checked for cleanliness and wear. If a deposit of graphite from the brushes is found, it may be removed by holding a piece of No. 00 sandpaper against the commutator while the armature is in motion. Ridges or pockets on the surface of the commutator will require the removal of the armature so that it may be "trued up" on a lathe. Only a light cut should be taken, and the mica separators between the bars of the commutators must be undercut from one sixty-fourth to one thirty-second inch after the truing operation. Although a special cutter should be used for this purpose a hacksaw blade ground to the proper thickness will serve in an emergency.

All electrical switch contacts should be sanded clean if pitted. Parts that have been badly burned should be replaced. At least once each year, the windings of the generator and motor should be inspected and, if found dry or cracked, coated with insulating varnishes or resins, carried in stock for this purpose.

WELDING CABLE

The welding cables that conduct the welding current from the power source to the work and then back to the source must be flexible, durable, well insulated, and large enough to carry the required current. Only cable that is especially designed for the purpose should be used for welding. A highly flexible cable must be used between the welding machine and the electrode holder. The ground cable—that is, the one which connects the work and the machine—need not be so flexible as the cable which connects the machine and the electrode holder.

Flexible cable is designed especially for welding. It derives its flexibility from its construction, since it is made of thousands of very fine wires enclosed in a durable paper wrapping which allows the conductor to slip readily within its rubber insulation when the cable is bent. The rubber also contributes to its flexibility. The ability of the cables to withstand wear and abrasion is provided by a tough, braided cotton reinforcing and by the composition and curing of the waterproof rubber covering, which also provides a smooth finish.

Two factors determine the size of the welding cable that should be used: the amperage rating of the machine, and the distance between the work and the machine. If either amperage or distance is increased, the cable size must also be increased. A cable that is too small for the amperage used will become overheated; a cable that is too small for the distance between the machine and the work will not carry sufficient current to the arc without becoming overheated. On the other hand, the larger sizes of cable are more difficult to handle. The best size, therefore, is one which is entirely adequate for the work but which is not unnecessarily large.

As a rule, the cable between the machine and the work should be as short as possible. Use one continuous length of cable, if the required length is not more than 35 feet. If it is necessary to use more than one length of cable, join the sections with insulated, lock-type cable connectors. Joints in the cable should be at least 10 feet away from the operator.

ELECTRODE HOLDERS

An electrode holder is essentially a clamping device for holding the electrode. It is provided with a hollow, insulated handle through which the welding cable is passed to connect with the electrode clamping device.

The advantage of an insulated electrode holder lies in the fact that it may be touched to any part of the work without danger of short circuiting. The clamping device is made of an alloy which is a good conductor of electricity and durable under high temperature and constant use. The clamp is designed to hold the electrode securely in any position and to permit quick and easy change of electrodes. An electrode holder should be light in weight to permit ease of handling yet sturdy enough to withstand rough usage. Typical electrode holders are shown in Figure 9-4.

Electrode holders are made in a variety of sizes, and each manufacturer has his own system of designation. However, any catalog description of an electrode holder gives the maximum amperage and range of electrodes by diameters which the holder will accommodate. The size used is dependent upon the amperage rating of the welding machine, that is, a larger holder must be used with a 300-amperage welder than with a 100-ampere machine. If the electrode holder is smaller than the type which should be used for a particular machine, the holder will overheat.

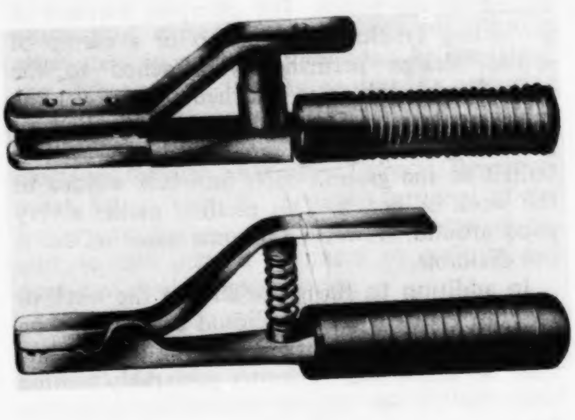
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Figure 9-4.—Electrode holders.

CAUTION: The fully insulated type electrode holder should always be used with a-c welding machines since this type holder gives the operator better protection from shock. These holders should be examined to see that there are no exposed screwheads or rivets which might come in contact with the operator and cause a serious shock.

GROUNDING

In many cases where trouble has occurred on a welding job it has been traced to a poor ground connection. Like any other electrical circuit, it takes only one poor connection to destroy the efficiency of the welding circuit.

There are three common methods used to attach the ground cable to the work; bolting, clamping, and tack welding. The bolt method of grounding is generally used when all welding is done on a bench or any permanent fixture with the lug on the end of the ground cable being bolted to the bench. The clamping method of grounding employs a C clamp or a clamp of special design permanently attached to the ground cable which is attached to the welding table or bench. The tack welded method of grounding employs a ground plate which is bolted to the ground cable and tack welded to the work or bench. This method makes a very good ground, however, in some cases its use is not desirable.

In addition to the grounding of the work or welding bench a ground should be provided on the welding machine for grounding the welding machine frame and enclosure preferably located near the power supply connection point. A power supply ground serves to reduce or eliminate shocks from stray currents as well as protect against imposing full supply voltage on the output terminals in the event of a breakdown of the insulation.

PROTECTIVE EQUIPMENT

Exposure of the eyes to the infrared and ultraviolet rays accompanying electric arcs often results in eye-burn or "sand in the eyes," as it is commonly called by welders, and may cause extreme pain for 24 to 48 hours. In addition to affecting the eyes, exposure to the arc will produce severe sunburn to portions of exposed skin.

To protect the eyes and face, a head shield should be worn. These shields are constructed of pressed fiber and are solid black in color to reduce reflection. They are light in weight and designed to insure comfort to the welder.

Protective shields are provided with a glass window whose standard size is 2 X 4 1/8 inches. The composition of the glass lens is such that it absorbs the infrared and ultraviolet rays and most of the visible rays from the arc. Table 9-1 lists the recommended lens shade number for various welding applications.

The welding lens is protected from metal splatter and breakage by a plain or a chemically treated, clear, nonsplatter glass covering the exposed side of the lens. Green-tinted flash goggles should be worn by the welder to protect his eyes from the flashes of other welders when he removes the shield for purposes such as inspecting his weld. They also protect his eyes when he is grinding, chipping, or cleaning slag. Flash goggles should be worn by all persons working in the vicinity of arc welding operations.

Table 9-1.—Recommended lens shade numbers

Lens shade number	Arc welding application (amperes)	Utraviolet (percent transmission)	Infrared (percent transmission)
6	To 30	0.2	1.5
8	To 75	.1	1.0
10	75 to 200	.1	.6
12	200 to 400	.05	.5
14	Over 400	.05	.3

During any arc welding operation, a continuous shower of sparks and hot molten metal is thrown off by the arc. These may cause burns if permitted to contact the skin; therefore, protective clothing must be worn to shield the welder from the spray and sunburn effects of the arc. Leather gloves, preferably of the gauntlet type, protective sleeves of leather, and leather aprons should also be worn at all times. Leather jackets provide excellent protection when welding in the vertical or overhead position. There are many other types of protective clothing, usually made of leather, such as trousers and leggings. Naturally, the type and amount of protective clothing you need will depend upon the position and size of the welding job.

In addition to wearing protective clothing, the welder should keep the collar button on his shirt fastened, and wear ankle-high shoes in preference to oxfords. It is also important that trousers without cuffs be worn and that the legs of the trousers be held down over the shoe tops. Bicycle clips are excellent for this purpose. The welder can protect the top of his head with a brimless white hat. Woolen clothing which offers more protection than cotton, should be worn, if possible.

When welding indoors, provisions should be made to remove smoke and fumes by mechanical means. When possible, all inside welding should be done in a special room or booth equipped with a suitable hood, ducts, and fan for exhausting the smoke and fumes and replacing with fresh air. If welding has to be performed in areas other than those mentioned above, as much ventilation as possible should be provided.

CURRENT AND POLARITY

To understand the meaning of polarity, its relationship to the arc welder, and its use, it is first necessary to become familiar with the basic principles of an electric current. A brief discussion of current and polarity is presented in the following paragraphs. For a more complete discussion, reference may be made to the Rate Training Manual, Basic Electricity, NavPers 10086-B.

Electric current is divided into two classifications–direct current (d-c), which is electricity flowing in one direction only, and alternating current (a-c), or current flowing alternately in opposite directions. In the latter, the direction of flow is continually reversing itself.

Electric current consists of a movement of electrons through an electrical circuit, the movement being from the negative terminal of the battery or generator through the electrical circuit to the positive terminal or pole of the source of electromotive force.

In a direct-current circuit, the polarity always remains the same, and the current always flows through the circuit in the same direction; however, in an alternating-current circuit the current continually reverses direction in keeping with the changes in polarity at the terminals of the a-c generator.

The polarity of the voltage drop across any electrical circuit, whether it be an arc, a single resistor, or an entire circuit, is determined by the direction of electron flow (current). The sum of all the voltage drops around the circuit equals the potential developed at the terminals of the generator.

ALTERNATING CURRENT

As previously mentioned, alternating current is current flowing alternately in opposite directions–the direction of flow is continually reversing itself. There are several advantages in using an a-c welding machine instead of a d-c machine. The advantages and disadvantages of the a-c welding equipment are discussed in the following paragraphs.

Advantages

One fundamental advantage of a-c welding is that it greatly reduces arc blow (distortion of the arc stream from the intended path). Another is the initial cost, which is generally cheaper for the a-c machine, and it is usually less expensive to maintain and operate. In small shops, where the only available power source is a single phase, the a-c welder is readily adaptable to a single or multi-phase power outlet of 110, 220, or 440 volts. The a-c welding transformers are quiet in operation and are highly recommended for welding in restricted places.

Disadvantages

The power available to small shops is often subject to "line surges" to which the transformer welder is extremely sensitive. Alternating-current welding is still handicapped by the fact that suitable electrodes have not been developed for generally satisfactory welding of copper, bronze, aluminum, and other nonferrous metals, as well as for certain hard-surfacing operations. Alternating current is constantly changing from straight to reverse polarity 50 percent of the time, giving no choice of polarity. Welding with a.c. requires that additional safety precautions be observed during welding operations. Operators are more subject to shock and burns than from d-c equipment.

DIRECT CURRENT

Direct current, as previously mentioned, is electricity flowing in one direction only. The d-c welding machine has several advantages over the a-c welding machine. The advantages and disadvantages of the d-c welding equipment are discussed in the following paragraphs.

Advantages

Direct current can be used for welding ferrous and nonferrous metals alike. It can be used where a much greater voltage drop on the electrode or on the plate is essential for satisfactory operation. In the case of many alloys, it is necessary to have a widely different voltage drop on one side of the arc than on the other. Either reverse or straight polarity may be applied to the welding job at hand, depending on the desired characteristics or nature of the weld. The positive side of the arc releases 65 to 75 percent of the heat when using the bare electrode.

Disadvantages

The welding operator must be continually on the lookout for arc blow, which is recognized by the persistency of the arc to flare wildly and tend to wander from the path along which the operator is attempting to conduct it. The initial cost of d-c welding equipment is more than the a-c equipment and is also more costly to maintain and operate. The d-c welding machines also require additional power requirements over those required for a-c equipment.

WELDING CURRENT AND VOLTAGE

The speed at which a welder travels and the quality of the weld will depend largely on the arc force, which is controlled by the amount of current and voltage being used. The limiting speed is usually the highest speed at which the surface appearance remains satisfactory. An increase in current increases the arc force and penetration. To use higher currents, larger size electrodes may be needed. In general, the first indication of excess current will be poor surface appearance of the weld.

As previously mentioned, arc force is controlled by regulating the proper amount of current and voltage, making it necessary for the welding operator to understand their function.

Voltage

Voltage across the arc while welding is determined by arc conditions–including length, temperature, and gaseous content, with length of arc the predominant factor. Generally speaking, as long as the current remains constant, arc voltage increases as the arc is lengthened and decreases as the arc is shortened. Experience has shown that the arc is more stable and easier to maintain without interruptions caused by air currents, magnetic conditions, etc., if the open circuit voltage is at least twice the actual arc voltage. Therefore, for practical purposes, the open circuit voltage should be at least 50 to 60 volts and should be adjusted to higher values when required by certain welding conditions.

Actual voltage across the arc while welding is not shown accurately by the voltmeter on the welding machine because it measures voltage across the terminals of the machine.

Current

In practical arc welding it is impossible to establish a set of current values that can be used satisfactorily under all conditions. The current to be used depends upon the size and type of electrode used, and the selection of the electrode depends, in turn, upon the nature of the welding job. The containers in which electrodes are furnished usually have instructions for the use of the electrodes and tables of recommended current values for various electrode sizes and welding positions. Manufacturers of electrodes can only generalize when publishing minimum and maximum current values for a certain size and type of electrode. The operator must learn to determine, by operating the welding equipment, whether he is using the proper current values to produce the desired results with maximum speed and minimum cost.

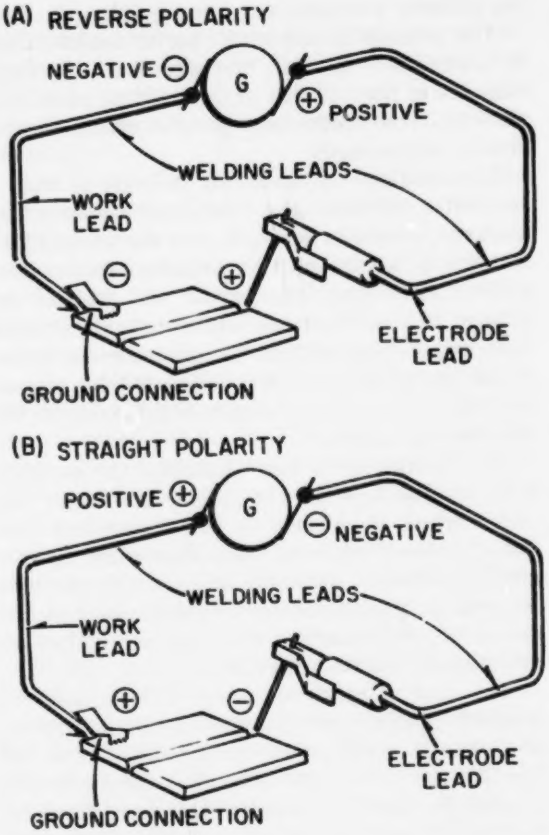
POLARITY

As previously mentioned, the polarity in a direct-current circuit always remains the same, and the current always flows through the circuit in the same direction. This is not the case in an alternating-current circuit since the current continually reverses direction in keeping with the changes in polarity at the terminals of the a-c generator. For this reason all the information given on polarity will apply to a direct-current circuit.

There was a time when nearly all welding was performed with direct current and bare metallic electrodes. Under these conditions it was found desirable to connect the positive side of the arc to the work and the negative side to the electrode. This applied a greater portion of the heat to the work, since the positive side of the arc releases 65 to 75 percent of the heat. With the electrode connected to a negative side of the arc, the polarity of the circuit was said to be straight. Figure 9-5 illustrates the hookup for straight and reverse polarity.

However, different jobs required different welding techniques. For instance, when welding cast iron or nonferrous metals it became important to decrease the amount of heat in the work metal. This was achieved by connecting the work to the negative side and the electrode to the positive. Since the connection had been reversed, the direction of current was reversed, and the welding polarity was said to be reversed, as shown in Figure 9-5.

In the early days of arc welding, it was necessary to change the cable connection at the machine, or at the work and electrode, if a change in the polarity was desired. With the advent of shielded metal arc welding, the change in the polarity to meet the conditions set up by the different coated electrodes became more frequent. Coated electrodes are manufactured for specific jobs, consequently some of them give better results with straight polarity than reversed polarity, while others produce satisfactory results when used with either polarity.


(A) REVERSE POLARITY

(B) STRAIGHT POLARITY

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Figure 9-5.–Straight and reverse polarity.

Manufacturers of welding machines soon realized that changing the cable connections to change the polarity for each job with different requirements was a cumbersome method. They therefore designed a polarity switch and mounted it on the control panel, making changing polarity a simple, easy, and quick operation.

The polarity to use with a particular electrode is established by the manufacturer. If doubt exists as to the polarity of the welding current at the electrode holder and ground clamp, simple checks can be made.

One method for checking polarity is with a voltmeter. When the voltmeter connection marked positive is connected to the ground lead and the other connection attached to the electrode holder lead, the needle will register the voltage if the leads are connected for straight polarity. If the voltage indicator needle drops below zero, the leads are connected for reverse polarity. Remember that in straight polarity, the electrode is negative.

If a voltmeter is not available, the polarity may be checked with a carbon electrode. Use two carbon electrodes of the same size and shape. Insert one of the electrodes in the electrode holder, establish an arc on a test plate, and run a bead. Change the welding cables and insert the other carbon electrode in the holder, establish an arc, and run a bead.

The carbon electrode used with straight or negative polarity will maintain its shape, the arc will remain stable, and the electrode will not become excessively hot. The electrode used with reverse or positive polarity will have a blunt, burned off end, the arc will be difficult to hold, and the electrode will become excessively hot.

Perhaps the quickest way to determine polarity is to use the E6010 electrode. This electrode is very sensitive to polarity and is designed to be used with d-c reverse polarity only. It gives so much better results when used correctly that polarity can be determined by merely observing its performance. When used with straight polarity, the E6010 electrode will emit large volumes of smoke and have an excessive "melt-off" rate.

FACTORS AFFECTING WELDS

In shielded metal arc welding there are several important factors which affect the finished weld and must be considered in obtaining good sound welds. Along with melting the electrode and base metal and their subsequent fusing, the arc has the additional and important ability to dig. This digging quality is referred to as arc force.

There is a definite force in the arc stream just as there is in a stream of water flowing from a hose. As water forced through a nozzle will dig dirt, so can the force of the arc stream be used to dig into the base metal. Each of the most common factors affecting welds is discussed in the following paragraphs and, in some instances, they are compared to the flow of water from a hose.

EFFECT OF CURRENT

An increase in current increases the arc force and penetration just as the increase in the volume of water through the size nozzle increases the digging power of the stream of water. To use higher currents, it may be necessary to use a larger size electrode. Generally, the first indication of an excess of current will be poor surface appearance of the weld.

EFFECT OF ARC LENGTH

A further comparison of the arc to a stream of water from a hose can be made to arc length. It is obvious that to dig deep into the dirt the nozzle must be kept near the ground to avoid spreading the stream of water into an ineffective spray.

When a long arc is held, heat is dissipated into the air, the stream of molten metal from the electrode to work is scattered in the form of splatter, and the arc force is spread over a large area resulting in a wide, shallow bead instead of a narrow one with deep penetration.

EFFECT OF TRAVEL AND SPEED ON PENETRATION

The important factor to observe in the utilization of arc force is causing the arc to travel at a sufficient speed to take advantage of the penetrating power of the arc force. This can be further illustrated by the comparison of water flowing from a hose.

The action of digging away dirt with a stream of water is only effective when the stream is directed at the dirt itself, not when directed into the pool of water which soon accumulates. If the stream of water is to keep digging, it must keep moving fast enough to stay ahead of the pool.

The same reasoning can be applied to welding. When the arc is advanced too slowly, a pool of molten metal forms beneath it, and the force of the arc is expended in the molten pool instead of penetrating into the base metal at the root of the joint. This molten metal flows along the joint under the arc and tends to solidify in the root of the weld without fusing to the base metal.

When the arc is advanced at the proper rate of speed, the arc force digs into the base metal and the result is good penetration. However, at a slow rate of arc speed travel, there is usually a small puddle of molten metal under the arc which dissipates the arc force and prevents maximum penetration.

The degree of penetration is proportional to the current used, combined with the effective use of the arc force. An increase in current will increase the arc force and penetration. However, if the speed of travel is too slow, the arc force will be wasted and there will still be less penetration than could be obtained by taking full advantage of the force.

In order to effectively use arc force for penetration, the speed of travel should be fast enough so that the electrode tip will be just ahead of the molten pool at all times, giving the arc force full opportunity to dig deep into the root of the joint. The limiting speed is usually the highest speed at which the surface appearance remains satisfactory.

EFFECT OF ANGULARITY

The angular position of the electrode to the work is also an important factor to be considered in arc welding. The angle of the electrode may determine to some extent the quality of the weld with freedom from undercutting and slag inclusions. The ease with which the filler metal is placed in the weld and the uniformity of fusion and weld contour as affected by the influence of surface tension and gravity on the molten metal may be the determining factor.

The proper angle to use for the different types of electrodes in various welding positions can be obtained from the electrode manufacturer.

EFFECT OF ARC BLOW

Welding with direct current involves a special problem known as ARC BLOW. It is important that you understand what arc blow is and that you know how to recognize it and what to do about it.

Arc blow is the result of a distortion in the electromagnetic field that surrounds a current-carrying conductor. The distortion of the field occurs as you approach any sudden turn in the welding–as, for example, when you are welding on an I-beam or a U-beam. When the field is distorted, a greater pull exists on one side than on the other. Consequently, the arc tends to blow out the side of the electrode, consuming the covering faster on that side than on the other side. The magnetic force takes control of the arc and causes it to pull this way and that in a wild and uncontrollable fashion. If the situation is not corrected immediately, at the first sign of trouble, the head will become intense and the arc will fluctuate wildly; in a very short time the arc will be lost, usually with an explosive burst that carries away the molten metal of the weld.

Arc blow can often be overcome by changing the direction of the current flow, by changing ground connections, by modifying the magnetic field with metal bars across the weld groove, by working toward a heavy tack or toward a completed weld, or by tilting the electrode. You will have to learn by experience which of these measures are most successful under various conditions.

Arc blow is much less noticeable when welding with alternating current than with direct current. As has been stated previously, this is due to the continuous change in the direction of current flow resulting in very little magnetic action with alternating current.

THERMAL AND MECHANICAL TREATMENTS

In some applications, welded areas require thermal or mechanical treatment. The thermal and mechanical treatments are necessary to restore the properties of the base metal affected by the heat of the welding arc, to relieve stresses, and to produce the desired structure in the base metal and filler metal.

The use of thermal and mechanical treatment is not required on most welds since the condition of the base metal and filler metal meets the job requirements. However, if any occasion should arise where it is necessary to use thermal or mechanical treatments to bring the welded area up to specifications, consult the Welding Handbook, Sixth Edition, published by the American Welding Society, for specific information on these treatments.

WELDING ELECTRODES

Electrodes are manufactured in a variety of metals and are available for use with any alloy that is classified as weldable by the manual shielded metal arc welding process. All electrodes used for this process in the Navy are suitable for use with direct current; some are also suitable for use with alternating current.

All metal electrodes now used by the Navy for manual shielded metal arc welding are of the shielded-arc type. These electrodes are made of wire of definite composition. The coatings are designed to improve the physical properties of the weld deposit and to control arc stability. The protection provided by the coating keeps oxygen in the air from combining with the molten metal of the weld deposit and causing porosity and oxidizing or burning of the weld. Without the protection of the coating, impurities would also be found in the welds, which would cause brittleness, low ductility, low strength, and poor resistance to corrosion. The coatings also serve to introduce alloys when welding low-alloy steels.

Iron powders have been added to the coating of many basic type electrodes. In the intense arc heat the iron powder is converted to steel, thus contributing additional metal to the weld deposit. When iron powder has been added to the electrode coating in relatively large amounts, the speed of welding is appreciably increased and the weld appearance improved.

There are two general types of coatings for electrodes: cellulose and mineral. Combinations of both types are also used. By burning, the cellulose coating forms a gaseous shield around the arc stream as well as a slag covering over the weld metal. The mineral-coated type depends upon the slag as a shield. The action of the shielded-arc electrode is illustrated in Figure 9-6.

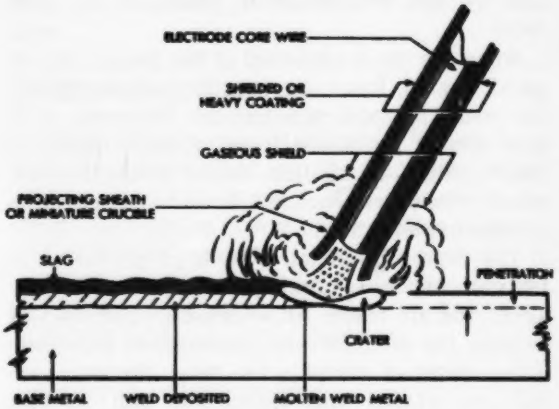

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Figure 9-6.—Action of shielded-arc electrode.

In the Navy, electrodes for manual shielded metal-arc welding must conform to certain specifications. Each specification covers several types of electrodes. For example, there are five types of electrodes for welding medium steel, each intended for a specific application with a given kind of welding current. Within a given type, electrodes are available in a variety of core wire diameters which, in some instances, are as small as 1/16 inch, and in other instances, as large as 3/8 inch. In length, electrodes may be 9, 12, 14, or 18 inches.

Coated electrodes should be kept stored in their original containers and in a dry area to prevent the coating from absorbing moisture from the air, especially when the relative humidity is very high. This is especially true of the iron powder and low hydrogen coatings, as an increase in their moisture content will produce unsatisfactory welds. In some cases where the electrodes have gotten wet, it will be necessary to dry out the electrode coatings by baking the electrodes in a furnace or oven before using them to weld.

CLASSIFICATION

Electrode classification tables are prepared and published jointly by the American Welding Society (AWS) and the American Society for Testing Materials (ASTM). These tables are available in booklet form from either of the above organizations. In order to illustrate these tables, the E60 series classifications are shown in Table 9-2.

As shown in the table, the electrode classifications contain the electrode classification number, type of coating, welding positions, and the recommended current and polarity.

Table 9-2.–Electrode classification

AWS-ASTM classification	Type of coating or covering	Capable of producing satisfactory welds in positions shown	Type of current
E60 Series.–Minimum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 psi (or higher).			
E6010	High cellulose sodium	F, V, OH, H	For use with d-c, reverse polarity (electrode positive) only.
E6011	High cellulose potassium	F, V, OH, H	For use with a-c or d-c reverse polarity (electrode positive).
E6012	High titania sodium	F, V, OH, H	For use with d-c, straight polarity (electrode negative), or a-c.
E6013	High titania potassium	F, V, OH, H	For use with a-c or d-c, straight polarity (electrode negative).
E6014	Iron powder, titania	F, V, OH, H	For use with d-c, either polarity or a-c.
E6015	Low hydrogen sodium	F, V, OH, H	For use with d-c, reverse polarity (electrode positive) only.
E6016	Low hydrogen potassium	F, V, OH, H	For use with a-c or d-c reverse polarity (electrode positive).
E6018	Iron powder, low hydrogen.	F, V, OH, H	For use with a-c or d-c, reverse polarity
E6020	High iron oxide	H-Fillets, F	For use with d-c, straight polarity (electrode negative), or a-c for horizontal fillet welds; and d-c, either polarity, or a-c, for flat-position welding.
E6024	Iron powder, titania	H-Fillets, F	For use with d-c, either polarity, or a-c.
E6027	Iron powder, iron oxide	H-Fillets, F	For use with d-c, straight polarity (electrode negative), or a-c for horizontal fillet welds; and d-c, either polarity, or a-c, for flat-position welding.
E6028	Iron powder, low hydrogen	H-Fillets, F	For use with a-c or d-c, reverse polarity.
E6030	High iron oxide	F	For use with d-c, either polarity, or a-c.

The abbreviations F, H, V, OH, and H-Fillets indicate welding positions as follows:

F = Flat
H = Horizontal
H-Fillets = Horizontal Fillets

V = Vertical
OH = Overhead
} For electrodes 3/16 in. and under, except 5/32 in. and under for classifications EXX14, EXX15, EXX16 and EXX18.

To understand the significance of classification numbers, consider the E6010 classification shown in Table 9-2. The E represents the word electrode. The first two numbers–60–refer to the minimum tensile strength in the stress-relieved condition, or 60,000 psi. The third number explains the possible welding positions, such as "1" for all welding positions (flat, vertical, overhead, and horizontal); or "2," which designates a greater restriction in choice by being usable only in the horizontal fillet and flat positions; whereas a "3" in the third number indicates that these electrodes may be applied in the flat position only. The fourth number in the classification indicates subgroups, and may be "0" through "8" under the present system. Table 9-3 defines the meaning of the numbers found in the sub-group.

Some electrodes are classified in five-digit numbers instead of four. In this case the first three digits apply to the minimum tensile strength as previously explained for the four-digit classification. Figures 9-7 and 9-8 illustrate the decoding of the four- and five-digit electrode classification numbers.

SELECTION

The first determining factor in the selection of the proper welding electrodes is the type of welding machine being used. If a d-c welding machine is being used, it is important to

Table 9-3.–Electrode classification

Last digit	Power supply	Type of slag	Type of arc	Penetration	Iron power in coating
0	(1)	(2)	Digging	(3)	0-10%
1	AC or DC rev. polarity	Organic	Digging	Deep	None
2	AC or DC	Rutile	Medium	Medium	0-10%
3	AC or DC	Rutile	Soft	Light	0-10%
4	AC or DC	Rutile	Soft	Light	30-50%
5	DC rev. polarity	Low hydrogen	Medium	Medium	None
6	AC or DC rev. polarity	Low hydrogen	Medium	Medium	None
7	AC or DC	Mineral	Soft	Medium	50%
8	AC or DC rev. polarity	Low hydrogen	Medium	Medium	30-50%

NOTES: (1) E-6010 is DC reverse polarity; E-6020 is AC or DC.
(2) E-6010 is organic; E-6020 is mineral.
(3) E-6010 is deep penetration; E-6020 is medium penetration.

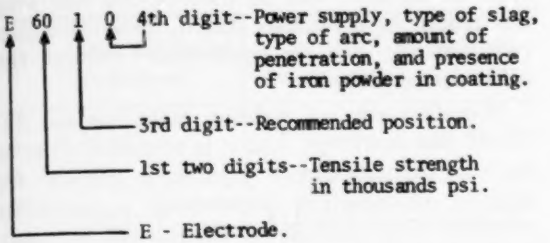
E 60 1 0
4th digit--Power supply, type of slag, type of arc, amount of penetration, and presence of iron powder in coating.
3rd digit--Recommended position.
1st two digits--Tensile strength in thousands psi.
E - Electrode.

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Figure 9-7.–Decoding a four-digit electrode classification number.

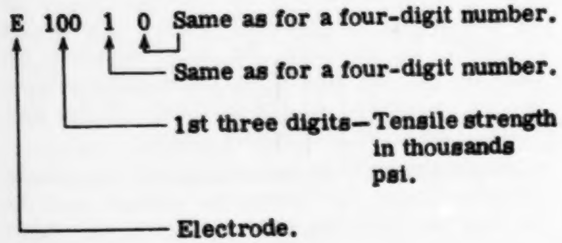
E 100 1 0
Same as for a four-digit number.
Same as for a four-digit number.
1st three digits–Tensile strength in thousands psi.
Electrode.

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Figure 9-8.–Decoding a five-digit electrode classification number.

consider the polarity. In some applications it is faster and more economical to use a straight polarity electrode, and there are other applications where reverse polarity electrodes are more satisfactory.

In shops equipped with a-c welding machines, only electrodes specified for use with a-c welders should be used. In addition to the type of welding equipment being used, there are several other factors which influence the selection of the proper electrode. They are listed in the following paragraphs.

Type or Kind of Metal to be Welded

This includes different metals such as mild, steel, high carbon steel, high tensile steel, stainless steel, cast iron, and any other metal that can be successfully arc welded.

Mechanical and Physical Properties Required of Fabricated Joint

This includes tensile strength, ductility, and hardness of resistance to wear.

Welding Position

The four welding positions are flat, horizontal, vertical, and overhead. When welding is done in a flat position the weld metal can be quite fluid. This results in the best appearing welds and maximum welding speed. Horizontal position welding requires electrodes possessing a very forceful penetration so weld metal will reach the root of the joint. Vertical and overhead joints require electrodes having the same characteristics as those used for horizontal welding. However, because there is an increased tendency of the molten metal to run out, electrodes for this type of welding must also produce a fast-cooling slag.

Condition of the Metal to be Welded

It is naturally desirable to have all joints as clean and free from grit, rust, and oil as possible. However, when this is not practicable, electrodes possessing characteristics of cleaning action and penetration should be selected. When the welding surface is coated with a plating metal, a strong arc is also necessary. However, a clean joint is always the most desirable.

Joint Preparation and Joint Fit Up

The joint influences welding speed and economy, making it desirable that parts fit well. The best electrode for welding a properly prepared joint is the one which affords the greatest speed after meeting the load and stress requirements of the joint. There are many cases, however, where "poor fit up" joints cannot be avoided. Then, an electrode that has excellent "poor fit up" qualities should be used. A "poor fit up" joint should not be confused with a properly spaced Vee joint having a backup strip.

WELDING PROCEDURES AND TECHNIQUES

The quality of a weld depends not only upon the welding process, but also upon the preparation of the metal and the equipment. These preparations, welding techniques, and specification for various arc welds are described in the following paragraphs.

CHECKING EQUIPMENT

The first step in preparing to arc weld is to make certain that all the necessary equipment is available and that the welding machine is properly connected and in good working order. Make certain that all connections are correct and tight. Particular attention should be paid to the ground connection, as a poor connection will result in a fluctuating arc, difficult to control. To make a good contact, the clamp should be cleaned and the point of contact thoroughly brushed.

The electrode is clamped to its holder at right angles to the jaws. Shielded electrodes have an end of the electrode free of coating to provide good electrical contact. Handle the electrode holder with care to prevent accidental contact with the bench or work, as such contact may weld it fast.

Before commencing to weld, the following list of items should be checked off:

1. Is the machine in good working order?
2. Have all connections been properly made? Will the ground connection make good contact?
3. Has the proper type and size electrode been selected for the job?
4. Is the electrode properly secured in the holder?
5. Has sufficient protective clothing been provided, and is it in good condition?
6. Is the work metal clean?
7. Does the polarity of the machine coincide with that of the electrode?
8. Is the machine adjusted to provide the necessary current for striking the arc?

SETTING UP THE WELDING MACHINE

The machine most likely to be found in the welding shop will probably be a d-c dual control type, rated at 200 amperes, and therefore this type of machine will be used in the following discussion. As previously stated, these units have two controls—one for open-circuit voltage, the other for amperage.

Manufacturers of welding machines use different dial markings, and it is advisable to refer to the manufacturer's operating manual for specific information concerning a particular machine. This manual will furnish the necessary information for adjustment to proper amperage and voltage values necessary for particular jobs. The general procedure, regardless of the machine dial markings, will follow the pattern described below.

After checking the polarity of the machine to make certain that it coincides with the electrode used, set the machine at the highest open circuit voltage within the limits of the job. This makes it easier to maintain the arc. Then set the amperes at the lowest recommended ampere setting, according to the diameter of the electrode. This is the preliminary setting.

Begin the weld at this setting and increase the amperes (heat) and lower the voltage until the arc and the resulting weld are satisfactory. Most welders run an experimental weld until the machine is adjusted to their individual liking. Good welders weld as much by ear as they do by eye, and they judge a good arc by the satisfying frying sound which it makes.

There are a number of variable factors affecting the machine setting. These include size and type of electrode, thickness of metal to be welded, type of joint, and skill and technique of the welder. With these variables to be considered, it is apparent that any set of current values could be merely generalization. Current values as published by different manufacturers vary considerably for the same classification and size of electrode.

Table 9-4 may be used as a general guide to the amperage required for welding steel with one commonly used type of electrode (MIL-type E6010 electrode). There is no need to memorize this information; it is included here merely to give you an idea of the range of amperages that you are likely to need for welding steel.

The proper welding current for a given set of conditions can be determined from the degree of

Table 9-4.–Amperage required for welding with MIL-Type E6010 electrodes

Electrode diameter (in inches)	Current, amperage	Voltage (arc volts)
3/32	40 to 80	23 to 25
1/8	75 to 125	24 to 26
5/32	110 to 170	24 to 26
3/16	140 to 215	26 to 30
7/32	170 to 250	26 to 30
1/4	210 to 320	28 to 34
5/16	275 to 425	28 to 34

electrode heat. If the electrode becomes excessively hot, it indicates that the current is too high. Welds of good quality cannot be made if the electrode overheats, and in such instances the current must be reduced or the size of the electrode increased. With proper current and electrode, a smooth, uniform bead should result.

PREPARATION OF WORK

The strength of any weld may be appreciably affected by lack of proper preparation of the work. Better strength is always obtainable when the work metal is clean and free of foreign matter. It is also highly important that the edges be prepared in a manner that will permit complete fusion without an excessive amount of heat. This is also necessary in order to minimize the amount of heat radiating from the weld to the surrounding base metal.

The same five types of joints are used to weld various forms of metal by either the oxyacetylene or the electric arc method. These are the butt joint, tee joint, lap joint, corner joint, and the edge joint. The kind of joint, thickness of metal, direction of welding, facilities for preparing the metal, and the load to which the weld is to be subjected govern the preparation of the joint. Figure 9-9 illustrates the preparation of edge and corner joints for arc welding.

Welds are commonly identified by the kind of joint involved, being referred to as butt welds, lap welds, edge welds, tee welds and corner welds. Obviously, a so-called butt weld may be of either the bead or groove type, according to the preparation of the joint.

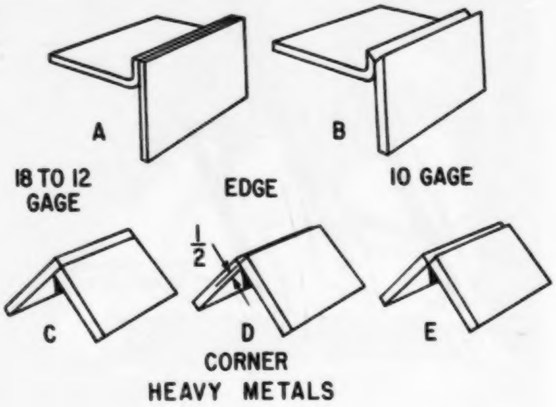

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Figure 9-9.–Preparation of edge and corner joints for arc welding. (A) For metals 18 to 12 gage; (B) for 10-gage metals; (C), (D), and (E) for heavier sheet.

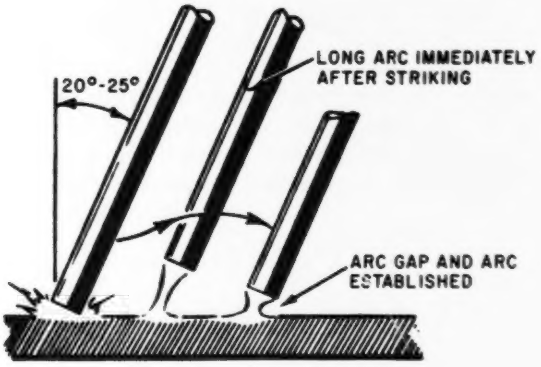
WELDING PROCESS

There is quite an art to arc welding and an individual can become a proficient welder only by practical experience. However, he must follow certain established procedures and develop the proper techniques to attain this skill. The basic procedures and some of the basic techniques are discussed in the following paragraphs.

Starting the Arc

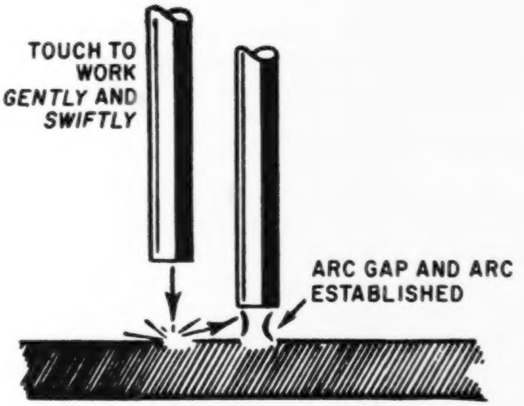
Two methods are used for starting the arc; the striking or brushing method (Fig. 9-10) and the tapping method (Fig. 9-11). In both methods, the arc is formed by short-circuiting the welding current between the electrode and the work surface. The surge of high current causes both the end of the electrode and a small spot on the base metal beneath the electrode to melt instantly.

In the striking or brushing method, the electrode is brought down to the work with a lateral motion similar to that of striking a match. As soon as the electrode touches the


20°-25°
LONG ARC IMMEDIATELY AFTER STRIKING
ARC GAP AND ARC ESTABLISHED

AM.548

Figure 9-10.—Striking or brushing method of starting the arc.


TOUCH TO WORK *GENTLY* AND *SWIFTLY*
ARC GAP AND ARC ESTABLISHED

AM.547

Figure 9-11.—Tapping method of starting the arc.

work surface, the electrode is raised to establish the arc (Fig. 9-10). The arc length or gap between the end of the electrode and work should be approximately equal to the diameter of the electrode at the uncoated end. When the proper length of arc is obtained, a sharp crackling sound can be heard.

In the tapping method, the electrode is held in a position vertical to the surface of the work. The arc is established by lowering the electrode, tapping or bouncing it on the work surface, and then slowly raising it a short distance, approximately the diameter of the electrode at the uncoated end (Fig. 9-11). When the proper length of arc is obtained, a sharp crackling sound can be heard.

If the electrode is withdrawn too slowly with either of the two arc-starting methods described above, it will stick or freeze to the plate or base metal. If this occurs, the electrode can usually be freed by a quick sidewise wrist motion to snap the end of the electrode from the plate. When this method fails, remove the electrode holder from the electrode, or stop the welding machine and use a light blow with a chisel to free the electrode from the base metal.

CAUTION: NEVER remove your helmet or face shield from your eyes as long as there is any possibility that the electrode will arc.

After the arc is struck, particles of metal melt off the end of the electrode and are fed into the molten crater of the base metal. The length of the electrode is thus gradually shortened. Unless you keep moving the electrode closer to the base metal, the length of the arc will increase. If the electrode is fed down to the plate and along the surface at a constant rate, a bead of metal will be deposited or welded on to the surface of the base metal. Before advancing the arc, hold it for a short time at the starting point to insure good fusion and to build up the bead slightly. Good arc welding depends upon good control of the motion of the electrode down to and along the surface of the base metal.

In advancing the electrode, it should be held at an angle of about 20-25 degrees in the direction of travel, as illustrated in Figure 9-12.

Relaxation while welding is important. Gripping the electrode holder too tightly causes the muscles used to control the electrode to be under tension, and the welder tires easily and loses the control essential to a good weld. To relieve some of the electrode holder's weight, the cable may be draped over the welder's shoulder or coiled in his lap. The holder is usually gripped in one hand, which may be supported by the other. You should use the position which is most natural and which suits the position of the job being performed.

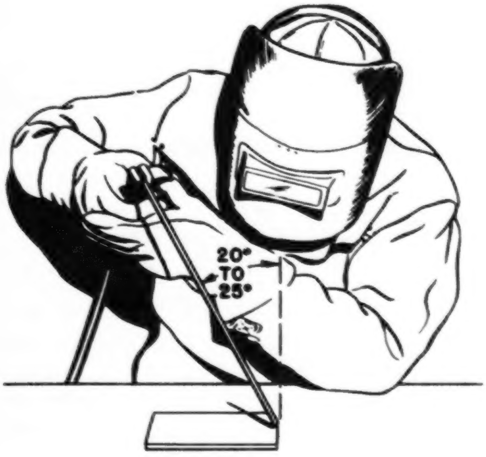


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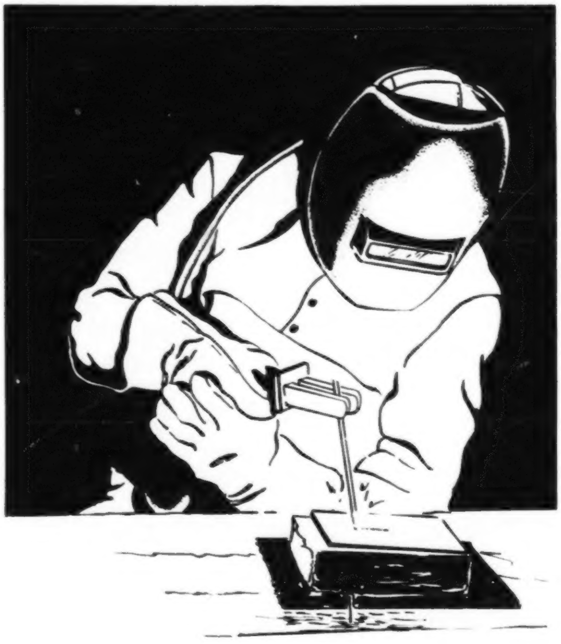
Figure 9-12.–Angle of electrode.



AM.546

Figure 9-13.–Proper technique for flat arc welding.

The hand gripping the electrode holder, as illustrated in Figure 9-13, is supported by the other hand for added steadiness. Elbows are kept close to the body and the cable is draped over the shoulder–an excellent position for the beginner. When you have learned to control the electrode with both hands and have gained confidence, you should develop the ability to control the electrode with one hand.

Running a Bead

A weld is a single bead or a combination of beads, and it is thus important for the arc welder to understand the difference between good and bad beads.

A bead is the metal deposited by one pass of the arc welding electrode. When a weld is made up of more than one bead, it is called a multiple pass weld.

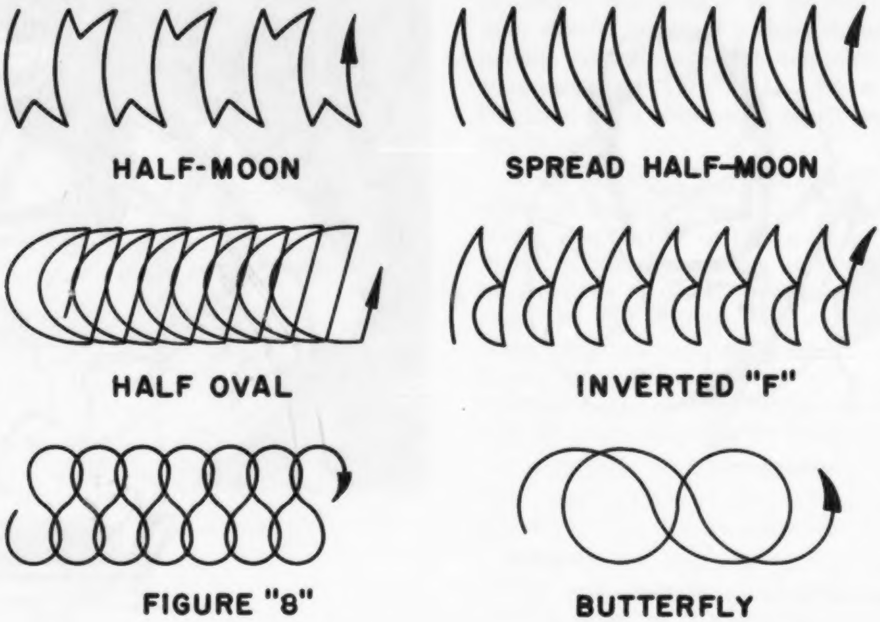
To form a uniform bead, the electrode must be moved along the plate at a constant speed, in addition to the downward feed of the electrode. The rate of advance, if too slow, will form a wide bead resulting in overlapping, with no fusion at the edges. If the rate of advance is too fast, the bead will be too narrow and have little or no fusion at the plate. When proper advance is made, no overlapping occurs, and good fusion is assured.

Weaving Technique

When depositing weld metal, it is often desirable to make the width of the deposit wider than is obtained by depositing a single bead. This is accomplished by a technique known as weaving, or moving the electrode from side to side during the forward motion.

There are a number of different weaving motions used in welding, but in all cases it is important that the motion used be uniform. Typical weaving motions are illustrated in Figure 9-14.

If the weave used is not uniform, or close enough, there is danger of poor fusion at the edges and of slag being trapped in the center.



HALF-MOON

SPREAD HALF-MOON

HALF OVAL

INVERTED "F"

FIGURE "8"

BUTTERFLY

AM.551

Figure 9-14.—Typical weaving techniques.

Breaking the Arc

There are two procedures used in breaking the arc. In one, the arc is shortened and the electrode moved quickly sideways out of the crater. This method is used in manual welding when electrodes are changed and the weld is to be continued from the crater.

The other method requires that the electrode be held stationary long enough to fill the crater and then gradually withdrawn. It is used in manual welding when it is desired to minimize or to eliminate the crater.

Restarting the Arc

If the arc is broken during the welding of a bead, a crater will be formed at the point where the arc ends. The arc may be broken by feeding the electrode too slowly or too fast, or when the electrode should be replaced. The arc should not be restarted in the crater of the interrupted bead, but just ahead of the crater on the work metal. Then, the electrode should be returned to the back edge of the crater. Figure 9-15 illustrates the procedure for restarting the arc.

From this point, the weld may be continued by welding right through the crater and down the line of weld, as originally planned.

Every particle of slag must be removed from the vicinity of the crater before restarting the arc. This prevents the slag from becoming trapped in the weld.

MULTIPLE PASS WELDING

Groove and fillet welds in heavy metals often require the deposit of a number of beads in order to complete a weld. It is important that the beads be deposited in a predetermined sequence in order to produce the soundest welds with the best proportions. The number of beads is, of course, determined by the thickness of the metal being welded.

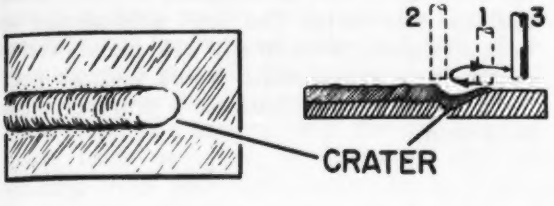


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Figure 9-15.—Restarting the arc.

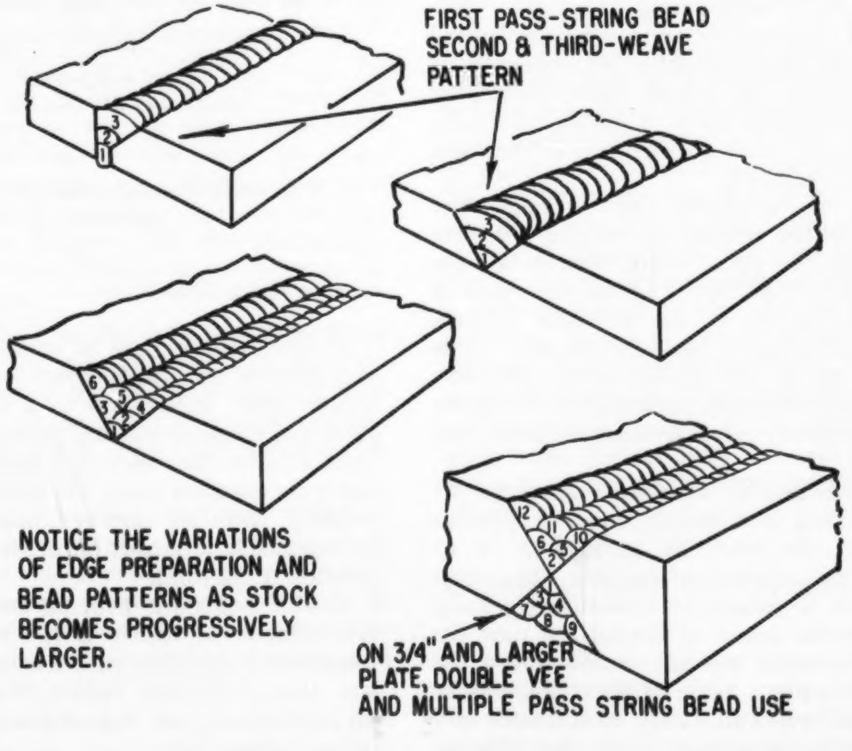
The sequence of the bead deposits is determined by the kind of joint and the position of the metal. All slag must be removed from each bead before another bead is deposited. This is most important, and will be discussed more fully in the section on joints and techniques of position welding. (See Fig. 9-16.)

TECHNIQUES OF POSITION WELDING

Each time the position of a welding joint or the type of joint is changed, it may be necessary to change any one or combination of the following: Current value, electrode, polarity, arc length, and welding technique.

Current values are determined by the electrode size as well as the welding position. Electrode size is governed by the thickness of the metal and the joint preparation, and the electrode type by the welding position. Manufacturers specify the polarity to be used with each electrode. Arc length is controlled by a combination of the electrode size, welding position, and welding current.

As it is impractical to cite every possible variation occasioned by different welding conditions, only the information necessary for the


FIRST PASS-STRING BEAD
SECOND & THIRD-WEAVE
PATTERN
NOTICE THE VARIATIONS
OF EDGE PREPARATION AND
BEAD PATTERNS AS STOCK
BECOMES PROGRESSIVELY
LARGER.
ON 3/4" AND LARGER
PLATE, DOUBLE VEE
AND MULTIPLE PASS STRING BEAD USE

AM.552

Figure 9-16.—Multiple pass groove welding of butt joints.

commonly used positions and welds is discussed here.

FLAT POSITION WELDING

There are four types of welds commonly used in flat position welding. They are the bead, groove, fillet, and lap joint welds. Each type is discussed separately in the following paragraphs.

Bead Welds

Welding a square butt joint by means of stringer beads involves the same techniques as depositing stringer beads on a flat metal surface. Square butt joints may be welded in one, two, or three passes. If the joint is welded with the deposition of one stringer bead, complete fusion is obtained by welding from one side. If the thickness of metal is such that complete fusion cannot be obtained by welding from one side, the joint must be welded from both sides.

When the metals to be welded are butted squarely together, two passes are necessary. If the metals must be spaced, three passes are required to complete the weld. In the latter case, the third pass is made directly over the first and completely envelops it.

It must be constantly kept in mind that beads, either the stringer or weaved type, are used to weld all types of joints. Even though the bead may not be deposited on the same type of surface, its action in the different welding positions and joints is basically the same as its action on the surface of flat metal. The same fundamental rules apply regarding electrode size and manipulation, current values, polarity, and arc lengths.

Bead welds can be made by holding a short arc and welding in a straight line at a constant speed, with the electrode inclined 5 to 15 degrees in the direction of welding. The proper arc can best be judged by recognizing a sharp crackling sound heard all during the time the electrode is being moved to and above the surface of the plate. Some of the characteristics of good bead welds are: They should leave very little spatter on the surface of the plate. The arc crater, or depression, in the bead when the arc has been broken should be approximately 1/16 inch deep. The depth of the crater at the end of the bead can be used as a measure of penetration into the base metal. The bead weld should be built up slightly, without any weld metal overlap at the top surface, which would indicate poor fusion. Figure 9-17 illustrates a properly made bead weld.

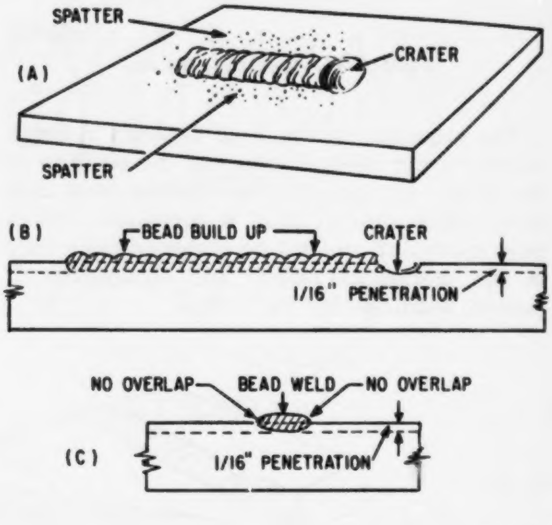


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Figure 9-17.—Properly made bead weld (flat position).

Groove Welds (Butt Joint)

Groove welding may be executed in either a butt joint or an outside corner joint. An outside corner joint corresponds to a single vee butt joint, and the same welding technique is used for both. It is for this reason that these two types of joints are classified under the heading of grooved welding. There are certain fundamentals which are applicable to groove welds, regardless of the position of the joint.

Groove welds are made on butt joints where the metal to be welded is 1/4 inch or more in thickness. Butt joints with a metal thickness of less than 1/4 inch require no special edge preparation and can be joined with a bead weld on one or both sides.

Groove welds are classified either single groove or double groove. This holds true whether the shape of the groove be a V, U, J, or any other form. Regardless of the position in which a single groove weld is made, it can be welded with or without a backing strip. If a backing strip is used, the joint may be welded from only one side. When a single groove weld is made without a backing strip, the weld may be made from one side, if necessary, although welding from both sides assures better fusion. The first pass of the weld deposit may be from either side of the groove. The first bead should be deposited to set the space between the two plates, and to weld the root of the joint. This bead, or layer of weld metal, should be thoroughly cleaned to remove all slag before the second layer of metal is deposited. After the first layer is cleaned, each additional layer should be applied with a weaving motion, and each layer should be cleaned before the next one is applied. The number of passes required to complete a weld is determined by the thickness of the metal being welded and the electrode size being used. As in bead welding, the tip of the electrode should be inclined between 5 and 15 degrees in the direction of welding.

Double groove welds are welded from both sides. This type of weld is used primarily on heavy metals to minimize distortion. This is best accomplished by alternately welding from each side–depositing a bead from one side and then from the other. However, this necessitates turning the plates over several times (6 times for 3/4-inch plate).

Distortion may be effectively controlled if the plates are turned over twice, as follows: Weld half the passes on the first side, turn the plate over and weld all the passes on the second side, then turn the plates over and complete the passes on the first side.

The root of a double groove weld should be made with a narrow bead, care being taken to insure that the bead is uniformly fused into each root face. When a few passes have been made on one side, the root on the opposite side should be chipped to sound metal to make the groove, and then welded with a single bead weld.

Any groove weld made in more than one pass must have the slag, spatter, and oxide carefully removed from all previous weld deposits before proceeding with the weld deposits over them. Figure 9-18 shows some of the common types of groove welds performed on butt joints in the flat position.

Fillet Welds

Fillet welds are used to make tee and lap joints. In welding tee joints in the flat position, the two plates are placed to form an angle of 90 degrees between their surfaces, as shown in Figure 9-19. The electrode should be held at an angle of 45 degrees to the plate surface. The top of the electrode should be tilted at an angle of about 15 degrees in the direction of welding. Light plates should be welded with little or no weaving motion of the electrode, and the weld is made in one pass. Fillet welding of heavier plates may require two or more passes. In that case, the second pass or layer is made with a semicircular weaving motion. In making the weave bead, there should be a slight pause at the end of each weaving motion in order to obtain good fusion to the edges of the two plates without undercutting them.

The procedure for making the lap joint fillet weld is similar to that used for making the fillet weld in a tee joint. The electrode should be held at an angle of 30 degrees to the vertical. The top of the electrode should be tilted to an angle of 15 degrees in the direction of welding. Figure 9-20 illustrates a typical lap joint. The weaving motion is the same as that used for tee joints, except that the hesitation at the edge of the top plate is prolonged in order to obtain good fusion with no undercut. When welding plates of different thickness, the electrode is held at an angle of 20 degrees to the vertical. Care must be taken not to overheat and undercut the thinner plate edge. The arc must be controlled in order to wash up the molten metal to the edge of this plate.

OVERHEAD POSITION WELDING

The overhead position is one of the most difficult in welding, since a very short arc must be maintained constantly, in order to retain complete control of the molten metal.

The force of gravity tends to cause the molten metal to drop down or sag on the plate. If a long arc is held, the difficulty in transferring metal

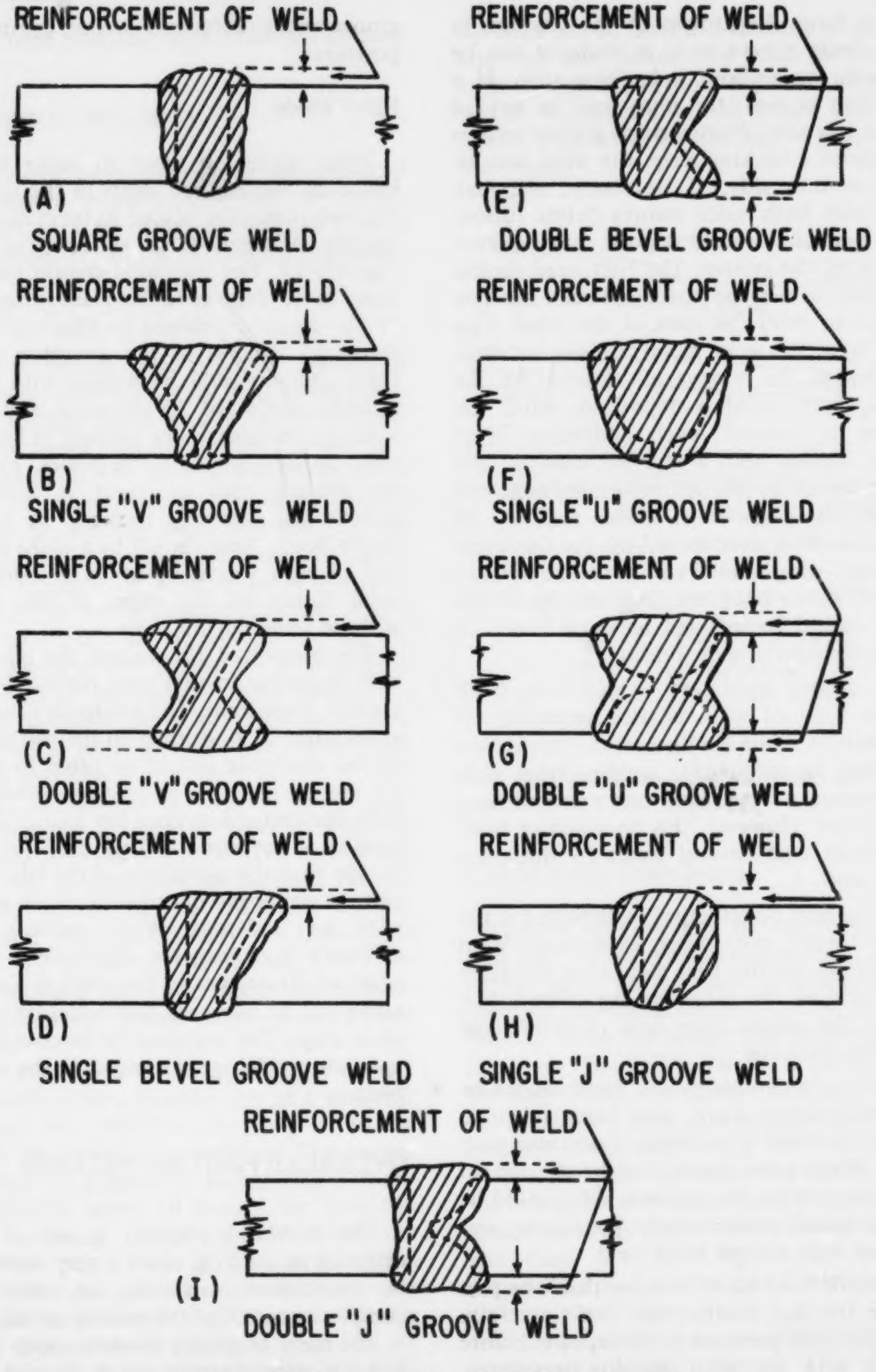
REINFORCEMENT OF WELD
(A)
SQUARE GROOVE WELD
REINFORCEMENT OF WELD
(E)
DOUBLE BEVEL GROOVE WELD
REINFORCEMENT OF WELD
(B)
SINGLE "V" GROOVE WELD
REINFORCEMENT OF WELD
(F)
SINGLE "U" GROOVE WELD
REINFORCEMENT OF WELD
(C)
DOUBLE "V" GROOVE WELD
REINFORCEMENT OF WELD
(G)
DOUBLE "U" GROOVE WELD
REINFORCEMENT OF WELD
(D)
SINGLE BEVEL GROOVE WELD
REINFORCEMENT OF WELD
(H)
SINGLE "J" GROOVE WELD
REINFORCEMENT OF WELD
(I)
DOUBLE "J" GROOVE WELD

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Figure 9-18.—Groove welds on butt joints in flat position.

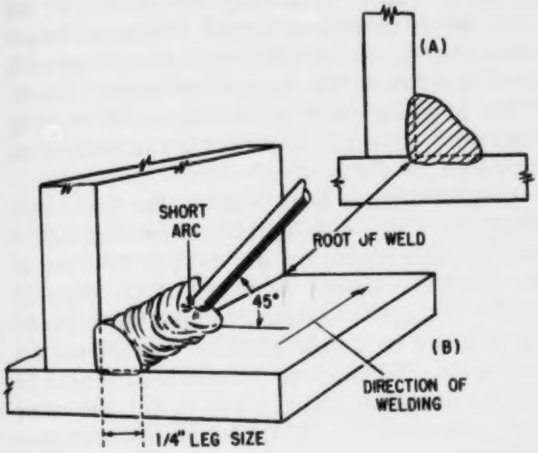

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Figure 9-19.–Tee joint fillet weld.

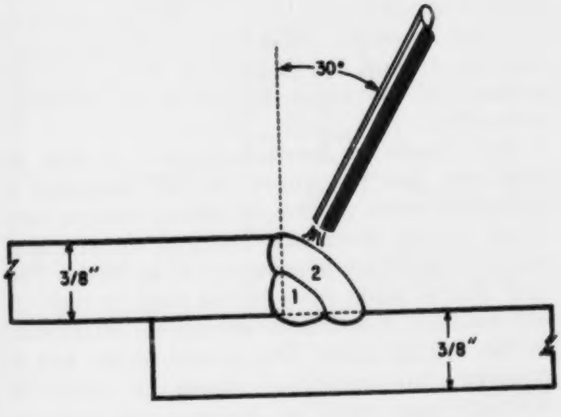

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Figure 9-20.–Lap joint fillet weld.

from the electrode to the base metal is increased, and large globules of molten metal will drop from the electrode and the base metal. The transfer of metal is aided by first shortening and then lengthening the arc. However, care should be taken not to carry too large a pool of molten metal in the weld. The procedures for making bead, groove, and fillet welds in the overhead position are discussed in the following paragraphs.

Bead Welds

For bead welds, the electrode should be held at an angle of 90 degrees to the base metal. In some cases, however, where it is desirable to observe the arc and the crater of the weld, the electrode may be held at an angle of 15 degrees in the direction of welding. Weave beads can be made by using the weaving motion. A rather rapid motion is necessary at the end of each semicircular weave in order to control the molten metal deposit. Care should be taken to avoid excessive weaving. This will cause overheating of the weld deposit and form a large pool of metal, which is hard to control.

Groove Welds (Butt Joints)

Overhead groove welds can be made more satisfactorily by using a backup strip. The plates should be prepared in a manner similar to that used for welding butt joints in the flat position. If no backup strip is used and the plates are beveled with a feather edge, the weld will burn through repeatedly, unless extreme care is used by the operator.

For overhead groove welding, bead welds are preferred to weave beads. Each bead deposited should be cleaned, and any rough areas should be chipped out before depositing the next bead. The electrode should not be too large, as this will prevent holding a short arc while obtaining good penetration at the root of the joint. The first pass should be made by holding the electrode at an angle of 90 degrees to the plate. The use of excessive current should be avoided. An excess of current will create a very fluid puddle, making control of the puddle very difficult.

Fillet Welds

When making fillet welds on overhead tee or lap joints, a short arc should be held, and there should be no weaving of the electrode. The electrode should be held at an angle of about 30 degrees to the vertical plate, and moved uniformly in the direction of welding.

The arc motion should be controlled to secure good penetration to the root of the weld and good fusion with the sidewalls of the vertical and horizontal plates. If the molten metal becomes too fluid and tends to sag, the electrode should be whipped away quickly from the crater ahead of the weld in order to lengthen the arc and allow the metal to solidify. The electrode should then be returned immediately to the crater of the weld and the welding continued.

Welding on heavy plates requires several passes to make the joint. The first pass is a string bead with no weaving motion of the electrode. The second, third, and fourth passes are made with a slight circular motion of the end of the electrode, while the top of the electrode is held tilted at an angle of about 15 degrees.

VERTICAL POSITION WELDING

The vertical position, like the overhead position just discussed, is also more difficult than welding in the flat position. Due to the force of gravity, the molten metal will always have a tendency to run down. To control the flow of molten metal, a short arc is necessary, as well as careful arc voltage and welding current adjustments.

The current setting for welds made in the vertical position should be less than those used for the same electrode size and type on welds made in the flat position. The currents used for welding upward on vertical plates are slightly lower than those used for welding downward on vertical plates. The procedure for making bead, groove, and fillet welds in the vertical position are discussed in the following paragraphs.

Bead Welds

When making vertical bead welds it is necessary to maintain the proper angle between the electrode and the base metal in order to deposit a good bead. In welding upward the electrode should be held at an angle of 90 degrees to the vertical. When weaving is necessary, the electrode should be oscillated with a "whipping up" motion. In welding downward, bead welds should be made by holding the top end of the electrode at an angle of about 15 degrees below the horizontal to the plate with the arc pointed upward toward the oncoming molten metal. When a weave bead is necessary, in welding downward, a slight semicircular movement of the electrode is necessary.

In depositing a bead weld in the horizontal plane on a vertical plate, the electrode should be held at right angles to the vertical. The top of the electrode should be tilted at an angle of about 15 degrees toward the direction of welding in order to obtain a better view of the arc and crater. The welding currents used should be slightly less than those required for the same type and size of electrode in flat position welding.

Groove Welds (Butt Joints)

Groove welding of butt joints in the vertical position is prepared in a manner similar to that used in welding butt joints in the flat position. In order to obtain good fusion with no undercutting, a short arc should be held, and the motion of the electrode should be carefully controlled.

Butt joints on beveled plates 1/4 inch in thickness can be groove welded by using a triangular weave motion. In groove welding butt joints in the horizontal position on identical plates, a short arc is necessary at all times. The first pass is made from left to right or right to left with electrode held at an angle of 90 degrees to the vertical plate. The second, third, and if required, any additional passes are made in alternate steps, with the electrode held approximately parallel to the beveled edge opposite to the one being welded.

Fillet Welds

When making fillet welds in either tee or lap joints in the vertical position, the electrode should be held at an angle of 90 degrees to the plates, or at an angle of up to 15 degrees below the horizontal, for better control of the molten puddle. The arc should also be held short to obtain good penetration, fusion, and molten metal control.

In welding tee joints in the vertical position, the electrode should be moved in a triangular weaving motion. The joint should be started at the bottom and welded upwards. A slight hesitation in the weave, as shown in Figure 9-21, will improve sidewall penetration and allow good fusion at the root of the joint. If the weld metal should overheat, the electrode should be lifted away quickly at short rapid intervals without breaking the arc. This will allow the molten metal to solidify without running down. The electrode should be returned immediately to the crater of the weld, in order to maintain the desired size of the weld.

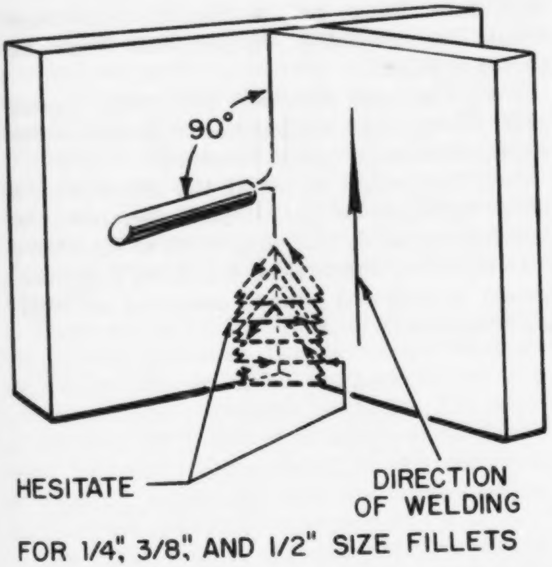

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Figure 9-21.–Vertical tee joint fillet weld.

When more than one layer of metal is needed to make a vertical tee weld, different weaving motions may be used. A slight hesitation at the end of the weave will result in good fusion without undercutting the plate at the edges of the weld. When welding lap welds in the vertical position, the same procedure is followed as that outlined for welding vertical tee joints, except that the electrode is directed more toward the one vertical plate. Care should be taken not to undercut either plate, or to allow the molten metal to overlap the edges of the weave. On heavy plate, lap joints require more than one layer of metal.

STANDARD WELDING SYMBOLS

The welding symbols shown in Figure 9-22 have been developed and standardized by the American Welding Society. These symbols are used to supply necessary welding information on drawings and blueprints. Since it is not practical to illustrate every application in which these symbols may be used, Blueprint Reading and Sketching, NavPers 10077-C, should be reviewed.

SAFETY PRECAUTIONS

Every weldor should have a thorough KNOWLEDGE of safety precautions relating to his job. But that is not all. Every weldor should also consider it his responsibility to carefully OBSERVE the safety precautions applicable to his job. In welding, one careless worker can cause serious injury not only to himself, but to other persons as well.

Bear in mind that safety precautions for the operation of welding equipment vary considerably because of the different types of equipment involved. Therefore, only general precautions on operating arc welding equipment are given here. For specific instructions on the operation, as well as maintenance and care of individual equipment, use the equipment manufacturer's instruction manual as a guide.

In regard to general precautions, know your equipment and how to operate it. Use only approved welding equipment, and see that it is kept in good, clean condition. Before starting to work, make sure that the welding machine frame is grounded, that neither terminal of the welding generator is bonded to the frame, and that all electrical connections are securely made. The ground connection must be attached firmly to the work, not merely laid loosely upon it.

Keep welding cables dry and free of oil or grease. Keep the cables in good condition and at all times take appropriate steps to protect them from damage. If it is necessary to carry cables

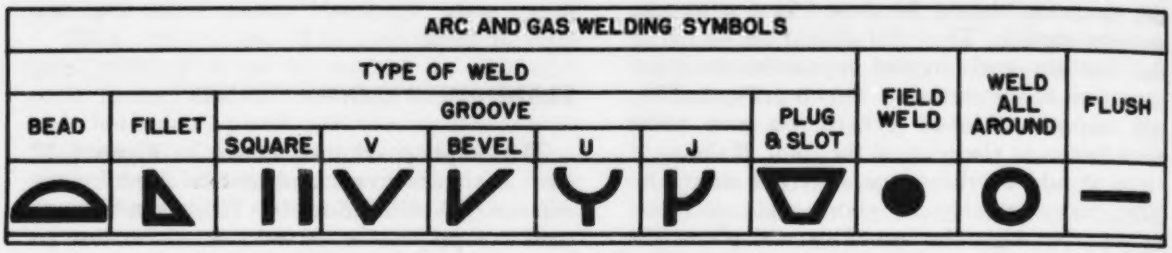

ARC AND GAS WELDING SYMBOLS
TYPE OF WELD
BEAD
FILLET
GROOVE
SQUARE
V
BEVEL
U
J
PLUG & SLOT
FIELD WELD
WELD ALL AROUND
FLUSH
AM.559

Figure 9-22.—Standard welding symbols.

some distance from the machine, run the cables overhead, if possible, using adequate supporting devices.

When using portable machines, take care to see that the primary supply cable is laid separately so that it does not become entangled with the welding supply cable. Any portable equipment mounted on wheels should be securely blocked, to prevent accidental movement during the welding operations.

When stopping work for any appreciable length of time, be SURE to deenergize the equipment. When not in use, the equipment should be completely disconnected from the source of power.

Keep the work area neat and clean. Among other things, make it a practice to dispose of hot electrode stubs in a metal container.

It is impractical to list all the safety precautions applicable to arc welding; therefore, the Arc Welding section of chapter 10 of NAVMAT P-5100, Safety Precautions for Shore Activities, should be reviewed prior to operating arc welding equipment.

CHAPTER 10

GAS SHIELDED ARC WELDING

Gas shielded arc welding is a metal joining development which has become one of the Navy's most important welding processes, especially for aluminum and magnesium alloys and other hard to weld materials. In the gas shielded arc welding process, a shielding gas is used to protect the electrode, arc, molten weld metal, and weld area from exposure to the atmosphere. The shielding gas is noncombustible and may or may not be inert (chemically inactive). The electrode used for this process may be nonconsumable, or it may be a consumable wire electrode that is fed automatically into the weld.

There are two different types of gas shielded arc welding processes. One is the gas tungsten-arc (GTA) process which employs the use of a nonconsumable tungsten electrode. The electrode does not burn off or supply metal to the joint. Necessary filler metal is added to the joint, as required, by the operator in a fashion similar to that used in oxyacetylene welding.

The other type is the gas metal-arc (GMA) process which employs the use of a consumable wire electrode that is fed automatically into the weld.

The two processes mentioned above were formerly known as tungsten inert-gas (TIG) welding and metal inert-gas (MIG) welding. These names were changed by the American Welding Society because carbon dioxide is used as a shielding gas when welding mild steel by the gas metal-arc process and carbon dioxide is not an inert gas.

GAS TUNGSTEN-ARC WELDING

Gas tungsten-arc (GTA) welding is a gas-arc welding process which uses an inert gas to protect the weld zone from the atmosphere. Heat for welding is provided by a very intense electric arc which is struck between a virtually nonconsumable tungsten electrode and the work. The principle of the inert arc is the same as the conventional electric arc discussed in the preceding chapter. The arc is actually the passage of electricity through atmospheric resistance between the electrode and the base metal. The current used may be either a.c. or d.c., depending on the material to be welded.

This process differs from gas metal-arc (GMA) welding (discussed later in this chapter) in that the electrode is not melted and used as a filler metal. On joints where filler metal is required, a filler rod is fed into the weld zone and melted with the base metal in much the same manner as used with oxyacetylene welding.

In any type of welding, the best obtainable weld is one that has the same chemical, metallurgical, and physical properties as the base metal. To obtain these conditions, the molten weld puddle must be protected from the atmosphere; otherwise, atmospheric oxygen and nitrogen will combine readily with the molten weld metal and result in a weak, porous weld. In GTA welding, the weld zone is shielded from the atmosphere by an inert gas which is fed through the torch. Either of two inert gases may be used, argon or helium. An arc in argon or helium gas is smooth and quiet. In argon the arc has an appearance similar to the oxyacetylene welding flame. In helium the arc is more ball-like in shape.

The GTA welding process has several advantages over the conventional arc welding process; and it also has some disadvantages which are discussed in the following paragraphs.

ADVANTAGES

Welds are stronger, more ductile, and more corrosion-resistant than welds made by the conventional arc welding process. The weld zone has 100 percent protection from the atmosphere; therefore, no flux is required. It is applicable to a wider variety of joints and no postweld cleaning is required. Since no flux is required, it eliminates flux or slag inclusions in the weld and there are no sparks, fumes, or spatter. Little or no filler metal is needed.

Efficient use is made of welding current; the machine operates only during actual welding operations, with a-c power. Other advantages are high speed, 3 to 12 inches per minute, with a minimum of distortion; efficient use of welding heat; and smooth, even welds with excellent strength and in some cases with only slight reinforcement.

DISADVANTAGES

Different types of machines and currents are required for different materials to be welded. For example, alternating current high frequency (ACHF) is used for welding aluminum while direct current straight polarity (DCSP) is used for heavy gage stainless steel. The initial cost of equipment is high and the gases used are expensive.

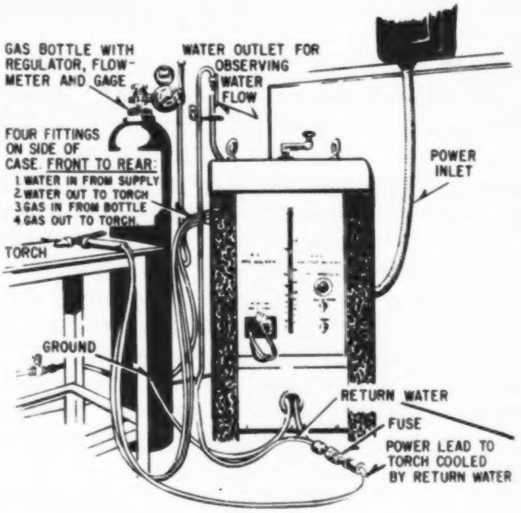
APPLICATION

As previously mentioned, the GTA welding process can be used to weld most metals; particularly the hard to weld metals such as aluminum magnesium corrosion-resistant steels, titanium, nickel, and nickel-base alloys. This process is also used widely for welding various combinations of dissimilar metals, and for applying hard-facing and surfacing materials to steel.

EQUIPMENT REQUIREMENTS

GTA welding equipment is produced by many manufacturers, and there are as many equipment designs as there are manufacturers. For this reason it is very important to remember when studying this chapter that the equipment being discussed is only one of the many types that might be found throughout the Navy. However, the functions of similar component parts of different makes of machines are identical although they may not appear to be so.

Basic equipment requirements for GTA welding consist of the torch plus additional apparatus to supply electric power, inert gas, and water. (See Fig. 10-1.)


GAS BOTTLE WITH REGULATOR, FLOW-METER AND GAGE
WATER OUTLET FOR OBSERVING WATER FLOW
FOUR FITTINGS ON SIDE OF CASE. FRONT TO REAR:
1 WATER IN FROM SUPPLY
2 WATER OUT TO TORCH
3 GAS IN FROM BOTTLE
4 GAS OUT TO TORCH.
POWER INLET
TORCH
GROUND
RETURN WATER
FUSE
POWER LEAD TO TORCH COOLED BY RETURN WATER

AM.561

Figure 10-1.—Typical GTA welding equipment.

The torch feeds both the welding current and the inert gas to the weld zone. The current is fed to the weld zone through the electrode, which is held firmly in place by the electrode holder. The inert gas is fed to the weld zone through a gas cup which screws on the end of the torch.

Power Unit

The power unit supplies alternating current through a transformer, or direct current through a motor generator. The type of current used depends largely on the material to be welded. The power source for operating a direct-current (d-c) welder can be supplied by any standard motor-driven generator with adequate amperage capacity for the job. Best results are obtained with an open circuit voltage of not more than 80 volts.

For a-c welding power, any standard transformer with an adequate amperage capacity for the job may be used. For best results the open circuit voltage should be from 60 to 100 volts, and the transformer should be a balanced wave type. Regular a-c power for GTA welding should have high-frequency current for stabilizing the welding arc. When high-frequency current is used, a normally open foot or torch switch is recommended to shut off this current before the torch is withdrawn from the weld. This prevents formation of a line arc that, with the gas protection removed, might cause oxidation and crater cracks in the weld metal.

In direct-current welding, the welding current circuit can be hooked up as either straight polarity or reverse polarity. The machine connection for direct-current straight polarity welding is electrode negative and work positive. For direct-current reverse polarity the connections are reversed and the electrode is positive and the work negative.

In straight polarity welding, the electrons, hitting the workpiece at high velocity, exert a heating effect on the plate; while in reverse polarity welding, just the opposite occurs. The electrode has to absorb the extra heat, which tends to melt off the end of the electrode. Therefore, reverse polarity requires a larger electrode diameter than straight polarity. For example, a 1/16-inch diameter pure tungsten electrode can handle 125 amperes of welding current with straight polarity. If the polarity was reversed, this amount of current would melt off the electrode and contaminate the weld. A 1/4-inch diameter electrode is required to handle 125 amperes of reverse polarity current safely.

Hand Welding Torches

There are various types of GTA welding torches available and, although not all torches have the same external appearance, their principle of operation is much the same. Figure 10-2 shows a schematic of a typical watercooled GTA welding torch. The torch illustrated is designed to perform several functions: (1) hold the electrode; (2) introduce an envelope of shielding gas around the electrode; (3) transmit current to the electrode; and (4) circulate cooling water throughout the holder.

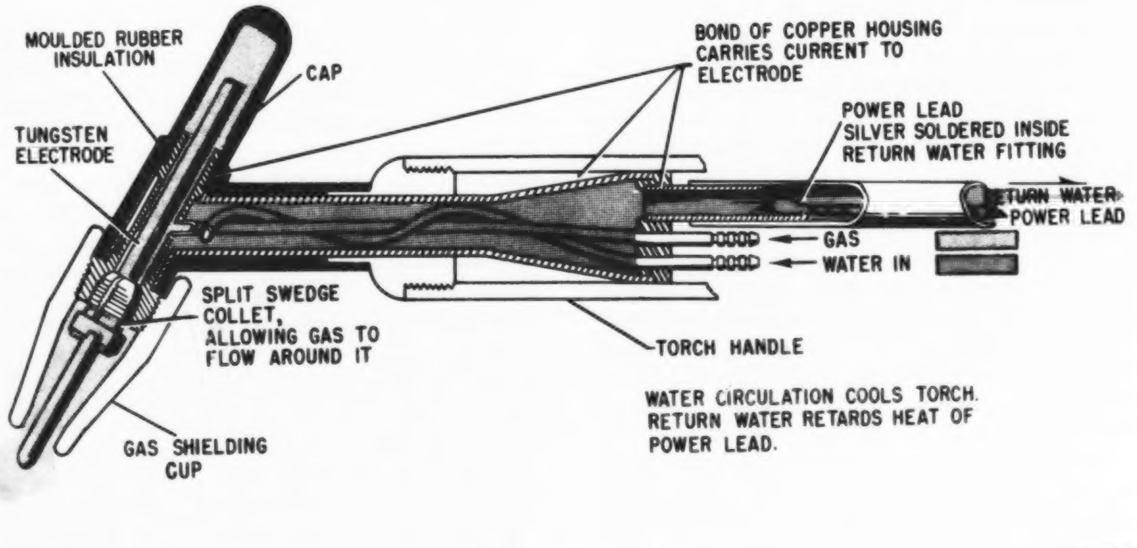

MOULDED RUBBER INSULATION
CAP
TUNGSTEN ELECTRODE
BOND OF COPPER HOUSING CARRIES CURRENT TO ELECTRODE
POWER LEAD SILVER SOLDERED INSIDE RETURN WATER FITTING
TURN WATER
POWER LEAD
GAS
WATER IN
SPLIT SWEDGE COLLET, ALLOWING GAS TO FLOW AROUND IT
TORCH HANDLE
WATER CIRCULATION COOLS TORCH. RETURN WATER RETARDS HEAT OF POWER LEAD.
GAS SHIELDING CUP
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Figure 10-2.–Typical water-cooled GTA welding torch.

The water-cooled torch is designed for GTA welding using either alternating current or direct current with straight or reverse polarity. Gas enters through a hose fitted to the rear of the handle, passes through the body of the torch, and emerges from the gas orifice in the torch head. Gas is then guided down toward the weld puddle by the shielding gas cup which surrounds the electrode.

Cooling water circulates through the torch and out around the power cable. The water cooling protects parts of the torch from excessive heat and permits the use of a minimum of insulation in the body of the torch. The torch is light and easy to manipulate.

The power cable is contained in the water discharge hose, and is water-cooled in such a manner that extremely high currents can be used without excessive power loss.

CAUTION: Be sure water lines are hooked up properly. Do not weld with water flow reversed. The water should cool the torch body before it flows over the power cable.

The torch is fully insulated to safeguard the operator against shock, and to prevent damage to the work from accidental arcing. Overheating of the torch, due to failure of the water supply, is prevented by a special fuse inserted in the cable circuit section of the water discharge line. Standard 3-ampere, 250-volt links can be used. Two fuse links must be used to accommodate maximum amperage capacity of the torch. Use of the torch at high amperages tends to deteriorate the shielding gas cup.

Electrodes for GTA welding are available in four types: pure tungsten (99.5 percent), tungsten with 1 to 2 percent thorium, tungsten with 0.3 to 0.5 percent zirconium and striped electrodes with a longitudinal strip of tungsten with 2 percent thorium on pure tungsten. These electrodes have a very high melting point and are practically nonconsumable—normal consumption is 0.001 to 0.005 inch per hour.

Tungsten electrodes of 99.5 percent purity are less expensive and are generally used on less critical operations than tungsten electrodes that are alloyed with thorium or zirconium A pure tungsten electrode has a relatively low current-carrying capacity and a low resistance to contamination.

Tungsten electrodes with 1 to 2 percent thorium are superior to pure tungsten electrodes in several respects. They have higher electron emissivity, better current-carrying capacity, longer life, and greater resistance to contamination. With these electrodes, arc starting is easier, and the arc is more stable.

Tungsten electrodes with 0.3 to 0.5 percent zirconium have properties that generally fall between those of pure and thorium containing (thoriated) tungsten. However, there is some indication of better performance in certain types of welding with alternating current. Striped electrodes, when used for a-c welding, combine the desirable stability characteristics of pure tungsten with the capacity and starting characteristics of thoriated tungsten.

Electrodes are available in 3- to 24-inch lengths and 0.010- to 0.250-inch diameters. The current-carrying capacity of all types of tungsten electrodes is affected by the type of electrode holder, the extension of the electrode from the holder, the position of welding, the shielding gas, and the type of welding current. The electrodes are held in place by a collet (Fig. 10-2). Electrode length is adjusted by extending or retracting the electrode through the collet clamping device.

The electrode, particularly in manual operations, will pick up contamination from the work caused in most cases by touching the workpiece. The life of the electrode can be extended by making sure that the electrode does not come in contact with the work during welding operations, and by choosing an electrode of the proper size for the current range being used. The electrode will deteriorate more rapidly when the welding current is too high or too low for the particular size electrode being used.

If the electrode comes in contact with the workpiece or worktable, a small bead or ball will appear at the contact end. This causes the arc to become unstable. This ball may be removed by grooving the electrode just above the fouled point with a file, then breaking it off with pliers. It is essential that the electrode be grooved to prevent splitting when the burned metal is broken off. This operation can be repeated as often as necessary until the electrode can no longer be clamped or held in the torch.

Ceramic and Metal Cups

Ceramic and metal cups are available in various diameters, shapes, and lengths. Length and shape are selected on the basis of joint accessibility and the required clearance between the cup and the work. The cup should be large enough to provide complete inert-gas coverage of the molten weld metal. Ceramic cups are acceptable when the welding current is less than 250 amperes. When higher currents are used, or when welding conditions are unusually severe, metal cups are used. Metal cups should never be allowed to come in contact with the metal being welded when the current is on.

Regulator

The regulator used on the inert-gas cylinder is identical in design to those used on oxygen cylinders. It is ruggedly built, and combines high sensitivity of control with a large flow capacity.

CAUTION: Always stand to the side when cracking the cylinder valve. Gage faces sometimes blow out when pressure is suddenly applied.

The function of the regulator is to reduce the high pressure in the cylinder to the desired working pressure, and hold that pressure without fluctuation or readjustment, until the cylinder is almost exhausted. Figure 10-3 shows a typical regulator, flowmeter, and pressure gage combination.

Flowmeter

Along with pressure reduction, successful GTA welding requires a constant flow of shielding gas. The gas flow rate is indicated by a graduated glass tube flowmeter (Fig. 10-3). As shown, the flowmeter is usually attached to the regulator, but it may be installed elsewhere in the gas line. The flowmeter should always be mounted vertically. Be sure you have the proper flowmeter for the gas being used or the flow indicated will be incorrect.

Flow is regulated by a needle valve of special design, and is measured by the position of the lightweight metal spinner inside a graduated glass tube. Flowmeters are calibrated in liters per minute (lpm) or cubic feet per hour (cfh). The selection of gas flow is a critical factor. A sufficient flow of gas is required during the welding operation to prevent oxidation of the weld metal. The weld zone must have 100 percent protection from the atmosphere. This flow will be found in the range of 4 to 15 liters per minute for argon, and 8 to 40 liters per minute for helium.

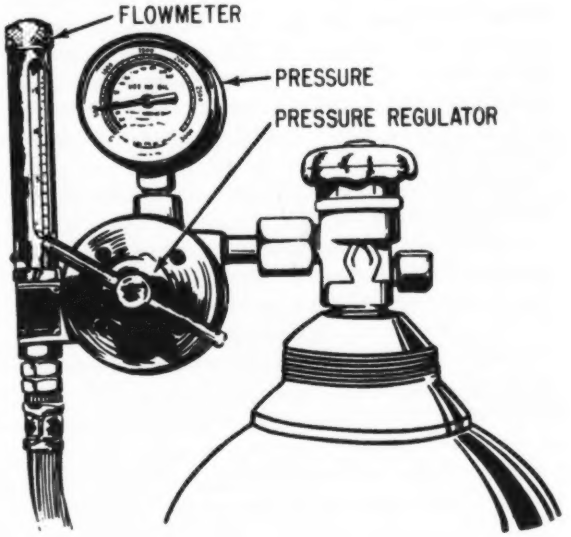

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Figure 10-3.—Regulator, flowmeter, and pressure gage.

The exact flow setting will depend on the type of joint, fit of the joint, and the material to be welded. Small differences in conditions can make considerable difference in the required flow. The distance the torch is held from the work will change the required flow sharply. A drafty shop will increase the required flow. An increase in welding speed, while generally acting to reduce gas consumption, will usually require an increase in gas flow.

Inert Gases

The inert gases used in GTA welding are argon or helium. An inert gas is defined as a gas that will not combine chemically with any known substance.

Whether the gas used in GTA welding is helium or argon, the gas must be of high purity and free of moisture, hydrogen, and hydrocarbons. While both argon and helium are used interchangeably, and in some instances have been mixed, each gas has advantages for certain applications.

Argon's density (weight per volume) is considerably greater than that of helium, but it offers less resistance to the passage of electricity than does helium. Because of the difference in electrical resistance, the heat produced by the arc in an atmosphere of helium is hotter than that developed in argon. The helium shielded arc also produces deeper penetration, but at the same time has a greater tendency to spatter. Because of its greater density, argon remains in the weld vicinity longer and provides a better cleaning action when welding aluminum and magnesium with alternating current. For these reasons, about one-third less argon than helium is needed to provide equal shielding.

No inflexible rule governs the choice of gas for any application. Either argon or helium may be used successfully for most applications with the possible exception of the welding of extremely thin material, for which argon is essential. Welding-grade helium and argon are both available in 99.9 percent purity.

The cylinders used for storing argon and helium are similar to those used for oxygen. Argon cylinders have a 242 cubic-foot capacity and are charged to approximately 2,200 psi. Helium cylinders have a 200 cubic-foot capacity and are charged to approximately 2,000 psi.

Almost pure shielding gas is required in gas shielded arc welding. Since any impurities in the cylinder will have a tendency to settle to the bottom, cylinders should always be replaced when the pressure in the cylinder reaches 25 psi.

Helium is stored in cylinders painted gray with one orange band at the top. Cylinders containing argon are also painted gray but have one white band at the top. The same care should be exercised in handling, setting up, and storing argon and helium cylinders as those prescribed for oxygen cylinders.

Water-Gas Shutoff Valves

Shutoff valves for water and gas are of two types, solenoid and manual. The solenoid valve is controlled electrically. The manual valve is shut off by hanging the torch on the hook provided on the valve. A water drain or recirculating system is necessary to carry away the water coming from the cooling system of the torch.

Gas should be permitted to flow after the arc is broken for a minimum of 5 seconds to a maximum of 40 seconds, depending on the diameter of the electrode. The electrode should be brought to a silvery-white appearance, without blue-black discoloration, which indicates oxidation.

PROTECTIVE EQUIPMENT

The protective equipment used for gas shielded arc welding is similar to that used in manual shielded metal arc welding. The operator should be properly protected from the arc rays. This requires suitable clothing to cover all exposed skin surfaces, and a welder's helmet with the proper shade of glass to protect the eyes and face. The recommended welding lens shade numbers for various welding applications are given in chapter 9, Table 9-1 of this manual.

SETTING UP AND ADJUSTING EQUIPMENT

In most cases GTA welding machines are delivered from the factory ready for installation in the shop. However, they must be set up and adjusted, making it necessary for shop personnel to be familiar with the important units on the machine and the power requirements. The manual supplied with the machine should be consulted in setting up and adjusting the machine. Some of the general requirements are discussed in the following paragraphs.

Power Requirements

For alternating-current welding, a single-phase transformer requiring a 220- or 440-volt, alternating-current supply is generally used. The power from the machine to the electrode and work is supplied through two terminals on the machine, marked GROUND and ELECTRODE. Always make certain that the welding cable attached to the torch is connected to the terminal marked ELECTRODE.

It is recommended that the welding cables be kept as short as possible to keep the dissipation of the high-frequency current to a minimum. If the welding cables are lying close together, or on a steel plate, the high frequency may in time break down the insulation on the welding cables, thereby weakening the high-frequency output at the welding arc.

For direct - current welding, a motor-generator unit powered by a 220- or 440-volt, 3-phase alternating-current supply is generally used. Like the alternating-current machine, two terminals located on the machine supply the power to the torch and work. One terminal is marked POSITIVE and the other NEGATIVE. However, unlike the a-c machine, the torch on the d-c machine may be connected to either terminal, depending upon the polarity to be used. It should be noted, however, that straight polarity is used in almost all cases.

Special Control Units

Several special control units have been developed to control automatically various phases of the welding process. Included among these units are a contactor unit which controls gas, water, and power automatically; a unit to shut off the high-frequency power; and a unit to shut off the welding power. These units may be used singly or in combinations, and their use conserves gas and water, reduces radio interference, and provides greater convenience in operation.

Water Coolant

The water coolant is required to protect parts of the torch and cable circuit from overheating. The water can run continuously, but it is more convenient to have either a manually controlled valve or an electrically controlled solenoid valve. A solenoid valve can also be used to control the gas and should be connected in parallel with the water solenoid valve.

Various torches are designed for different current ranges, and the amount of water required for adequate cooling will vary. To insure that the torch is adequately cooled, always check the manufacturer's specifications for the proper pressure and temperature of the water to be used to cool the torch and cable circuit.

High-Frequency Unit

The high-frequency unit of the GTA welding machine is used to introduce a high-voltage, high-frequency, low-power additional current into the welding current. The high frequency produces a low-intensity arc, which jumps the gap between the electrode and the workpiece and pierces the oxide film, forming a path for the welding current to follow.

Introducing this high-voltage, high-frequency current into the welding current gives the following advantages:

1. The arc can be started without touching the electrode to the work.
2. Better arc stability is obtained.
3. A longer arc is possible.
4. The tungsten electrodes will have a longer life.
5. Use of wider current ranges for a specific diameter electrode is possible.

The high-frequency unit of a GTA welder is controlled by a switch located on the front of the machine. Welders which are designed to supply alternating current have a two-position switch. In the OFF position there is no high frequency and in the CONTINUOUS position the high frequency remains on as long as the contactor is depressed.

Welders which are designed to supply either alternating or direct welding current have a three-position switch. The third position is the START position. The START position is used when welding with direct current; high frequency is used in this position only to help start the arc. In the START position the high frequency will shut off automatically as soon as the arc is initiated.

When using the GTA welder for regular arc welding, the high frequency is not required, and the switch should be in the OFF position.

The output of the high-frequency unit is controlled by the high-frequency rheostat. The highest position provides the greatest high-frequency output and the greatest distance at which the high frequency will establish and maintain an arc from the tungsten electrode to the work. Once the electrode is hot, the jumping distance of the arc from the electrode to the work will increase, as both heat and high voltage ionize the inert gases used in the welding process.

Welding Current Controls

The welding current is controlled by various methods. The current for the GTA welder illustrated in Figure 10-1 is controlled by a handcrank on top of the housing. An indicator, visible through a slot in the front of the machine, indicates the current output.

Other welders have several current ranges which are selected by moving a lever to the desired range. On these machines, current control rheostats are generally used for fine adjustments within the selected range.

The current settings for GTA welding depend on the size of the electrode, speed of travel, thickness of material, and the amount of heat dissipation into surrounding jigs and fixtures.

GTA welders designed to produce both direct and alternating welding current have a current selector. This selector has an alternating-current high-frequency stabilized (ACHF), a direct-current straight polarity (DCSP), and a direct-current reverse polarity (DCRP) position. NOTE: On some machines the high-frequency is not automatically selected along with the alternating current. On these machines the selector would be set to the a-c position and a manually operated switch would have to be actuated to provide the high frequency.

The type of current used depends on the type of metal to be welded. Alternating-current high frequency (ACHF) is generally recommended for aluminum and magnesium. Direct-current straight polarity (DCSP) is used for all other materials. Direct-current reverse polarity may be used, as needed, when the machine is being operated as a regular arc welder without the use of shielding gas. DCRP is seldom used with GTA.

Inspection and Lubrication

The interior of the welder should be inspected and cleaned at least once a year. Accumulations of dirt and dust can be best removed by using compressed air.

Occasional lubrication of the threaded shaft and sliding mechanism of the moving coil is essential, especially when the unit is in continuous service. The grease used should have a high melting point and should be evenly distributed on threads of shaft and guides. Use grease sparingly to protect the windings of the coils from lubricating material.

WELDING PROCEDURES AND TECHNIQUES

Before setting up for a job, make a check on the equipment needed. In general, the items listed below will fill the bill for most jobs.

A-c or d-c welding machine.
Inert arc torch.
Source of running water.
Source of inert gas.
Hose.
Regulator (single or double stage).
Water flowmeter or visible flow of water.
Tungsten electrodes of suitable size (polished).
Gas cups for corresponding sizes of electrodes.
Protective clothing.
Leather gloves.
Head shield with proper shade lens.
Rubber floor mat.
Pliers and tongs.
Clamps, backing plates, or jigs.
Extra fuses.
Filler rods, if required.

After material and equipment are assembled and set up in a welding booth or curtain area, the next step is to select the right type of current to be used, as shown in Table 10-1. However, it should be kept in mind that figures given in any table in this chapter are to be used only as a basis from which to work. The actual settings for best results can be obtained only through experience.

Aluminum and Aluminum Alloys

The GTA welding process is particularly adapted to the welding of aluminum and aluminum alloys. Sound welds may be made without the use of flux. Dispensing with flux is a definite

Table 10-1.–Selecting the right type of current

Material	High-frequency stabilized alternating current	Direct current	
		Straight polarity	Reverse polarity
Magnesium up to 3/16 inch	1	N. R.	1
Magnesium above 3/16 inch	1	N. R.	N. R.
Magnesium castings	1	N. R.	2
Aluminum	1	N. R.	N. R.
Aluminum castings	1	N. R.	N. R.
Stainless steel 0.015 to 0.050 inch	1	2	N. R.
Stainless steel 0.050 inch and up	2	1	N. R.
High-carbon steel 0.015 to 0.050 inch	1	N. R.	N. R.
High-carbon steel 0.050 inch and up	2	1	N. R.
Cast Iron	2	1	N. R.
Brass alloys	1	1	N. R.
Everdur	2	1	N. R.
Monel	2	2	N. R.
Silver	2	1	N. R.
Hastelloy alloys	1	2	N. R.

1. Excellent operation—first preference.
2. Good operation—second preference.

N. R. —Not recommended.

advantage since flux removal from aluminum welded joints is extremely important to avoid corrosion. Although all of the aluminum alloys except 2024 and 7075 are considered weldable by the gas shielded arc process, there are certain restrictions, as described in the following paragraphs.

EFFECTS OF WELDING.–The heat of welding decreases the strength of both the nonheat-treatable and heat-treatable aluminum alloys except when the alloy is in the annealed condition. In some cases, the resistance to corrosion is also lowered.

The effects of strain hardening in the nonheat-treatable alloys are partially or wholly destroyed by heat, depending upon the temperature attained coupled with the time at temperatures above 400° F. These alloys are not affected as far as corrosion resistance is concerned.

The effects of solution heat treatment and precipitation treatments for heat-treatable aluminum alloys are adversely affected by the heat of welding. The extent increases with temperature and time at temperatures above 400° F. The alloys containing substantial amounts of copper (alloys 2014 and 2017) suffer not only from loss of strength but also from loss in resistance to corrosion when subjected to the heat of welding.

In view of the above, heat-treatable aluminum alloys that have been welded must be properly reheat treated before being used on aircraft. Heat treating after welding dissolves soluble constituents in the weld metal and all of the coarse and fine precipitated particles in the base metal. A more homogeneous condition results throughout the material. Quenching retains this solid solution condition while subsequent precipitation, at room temperature or at a moderately elevated temperature when artificial aging is employed, takes place fairly uniformly in the form of finely divided particles. Thus, the maximum strengths and resistance to corrosion of the base metal are realized. There is a sacrifice in ductility, however, and the strength of the joint is dependent upon that of the cast material in the weld zone.

NOTE: Alloys 2024 and 7075 are not fusion welded because of hot cracking and impairment of corrosion resistance. However, both of these alloys are spot and seam welded extensively.

CURRENT REQUIREMENTS.–Current requirements for the most commonly used metals are shown in Table 10-1. As shown in the table, first preference for aluminum is high-frequency stabilized alternating current.

The low-intensity arc produced by this high-frequency current provides a path easily followed by the main welding current. The welding arc can be started easily without the electrode actually contacting the work, and a longer arc can be used during welding. With alternating current stabilized in this manner, good welds can be made.

Current range (amperage) depends upon the size electrode, thickness of the metal, and the type of joint to be welded. Table 10-2 lists the general operating data for aluminum.

Table 10-2.–General operating data for aluminum

Aluminum				
Thickness (inch)	Current range (amperes)	Argon flow (cubic feet per hour)	Rod size where required (inches)	Arc speed (inches per minute)
0.025	10-75	10	1/16	10-40
0.031	20-75	10	1/16	10-40
0.0375	35-75	10	1/16	10-40
0.050	50-125	14	3/32	10-40
0.0625	70-130	14	3/32	10-40
0.078	80-150	14	1/8	10-40
0.109	150-175	14	1/8	20-30
0.125	160-200	14	3/16	6-25
0.195	175-200	14	3/16	4-20
0.250	150-200	20	3/16	2-10
0.375	150-225	25	3/16	2-8
0.500	300-450	30	1/4	5-10

TORCH ADJUSTMENT.–The correct size electrode and corresponding gas cup are selected according to the thickness of the material to be welded.

The electrode should be polished with steel wool before installing it in the torch. Cleaning of the electrode is important since the appearance of the finished weld is improved by the cleanliness of the electrode.

Install the electrode in the torch so that the extension is 1/8 to 1/4 inch beyond the end of the gas cup for butt welding and 1/4 to 3/8 inch for fillet welding.

CAUTION: ALWAYS MAKE CERTAIN THAT THE WELDING CURRENT IS OFF BEFORE ADJUSTING THE ELECTRODE.

SELECTION OF FILLER ROD.–The selection of the proper filler rod is necessary in order to obtain a weld of high strength and good corrosion resistance. For alloys 1100 and 3003, 1100 filler rod may be used. For other aluminum alloys, 4043, 5154, 5356, or 5456 rod should be used.

PREPARATION OF METAL.–Cleanliness is very important. Parts to be welded should be free of oil, grease, and dirt. Combustible materials in the path of the arc will burn and contaminate the gas shielding. If filler rod is used, it should also be cleaned.

Oil or grease should be mechanically or chemically removed. An abrasive disc sander is recommended for mechanical cleaning. Chemical cleaning should be performed, using a caustic bath followed by a sulfuric acid brightening bath. Do not use a wire brush or nitric acid, as this will contaminate the weld.

STARTING THE ARC.–It is possible to start the arc without actually contacting the work. Grasp the torch in a comfortable position. Hold the torch in a horizontal position about 2 inches above the work, or starting block, then quickly swing the torch down toward the work or starting block, so that the end of the electrode is 1/8 inch above the work, or starting block. This motion will start the arc. Figure 10-4 illustrates the procedure for starting the arc.

The downward motion should be made rapidly to provide the maximum amount of gas protection to the weld zone. If the end of the electrode is too far from the work when the arc starts, it will cause oxidation of the weld.

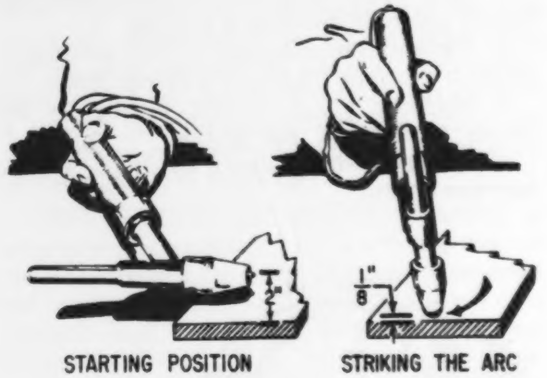

Figure 10-4.–Starting the arc.

The arc can be started with a-c or d-c power on the work itself or on a heavy piece of copper or scrap steel and then carried to the starting point of the weld. Do not use a carbon block for starting the arc, as the electrode will become contaminated, causing the arc to wander.

In making the first start with a-c power with a cold electrode, the distance the arc will start is much shorter than when the electrode is hot. When starting to weld with a hot electrode, the motions must be rapid, as the arc tends to start before the torch is in the proper welding position. This procedure for starting the arc can be used on all types of materials to be joined by the GTA welding process.

BREAKING THE ARC.–To stop the arc, merely snap the electrode rapidly back to the horizontal position, as shown in Figure 10-5. This motion is just the reverse of the starting procedure.

This motion must be fast so that the arc will not mar or damage the weld surface or work. When the electrode is hot the arc will jump a greater distance. This procedure for breaking the arc can be used on all types of materials.

ARC BLOW.–With the torch held stationary, the points at which the arc leaves the electrode and strikes the work may often shift and waver without apparent reason. This is known as arc blow, and is generally caused by one of the following reasons:

1. Low electrode current density–amperage for the electrode diameter is too low.
2. Carbon contamination of the electrode–caused by starting the arc on a carbon block.
3. Magnetic effects–caused usually by improper location of the ground.
4. Air drafts–in excessive air drafts, the arc becomes erratic.

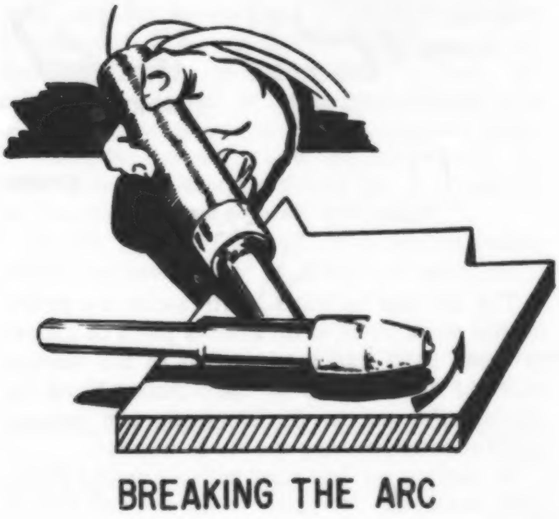

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Figure 10-5.–Breaking the arc.

The first two causes are distinguished by a very rapid movement of the arc from side to side. The third cause will usually displace the arc along the entire length of the weld. The fourth will cause various amounts of arc wandering, depending on how severe the air drafts are.

PREHEATING.–It is possible to weld aluminum up to 3/4 inch thick by hand without preheating. However, thicknesses over 3/4 inch will require a preheat of 300° to 400° F.

By preheating, the operator can work more easily and complete the weld faster. Preheating can be accomplished in special preheat ovens or by gas flames directed on the work in such a manner that they do not disturb the gas shield.

WELDING PROCEDURE.–After the arc has been started, hold the torch at an angle of approximately 75 degrees to the surface of the work. The starting point on the work is first preheated by moving the torch in a small circular motion until a molten puddle 3 to 5 times the thickness of the material is developed.

The end of the electrode should be held approximately 1/8 inch above the work. When the puddle becomes bright and fluid, move the torch slowly and steadily along the joint at a speed which will produce a bead of uniform penetration and width. No oscillating or other movement of the torch except for a steady motion forward is required.

When filler rod is required, the rod is held at an angle of approximately 15 degrees to the work, and just clear of the arc stream. Once the puddle has been developed, move the torch to the rear of the puddle, and add filler rod by quickly touching the leading edge of the puddle. Add only a small amount of rod. Remove the rod and bring the torch back up to the leading edge. When the puddle is again bright, repeat the above steps.

Arc speed is governed by the amount of current and thickness of material. Speed should be adjusted to obtain a bead of uniform height and width. The penetration should be uniform on the underside of the work. Good penetration is indicated by a very small, smooth bead. The controlling factors affecting a good weld are as follows:

1. Torch angle.
2. Arc length.
3. Arc speed
4. Electrode condition.
5. Joint design.

Some of the precautions to observe when running the bead follow. No attempt to add filler rod should be made until the puddle has been developed. Do not insert the filler rod in the arc stream or considerable spatter and excessive melting of the filler rod will result. Do not attempt to hold the filler rod in the molten puddle. The amount of filler rod determines the buildup of the bead, and little or no buildup is necessary.

INSPECTION OF WELD.–Inspection of the finished weld is very important not only to make certain that it meets all specifications but also to determine if the proper welding procedures were used. Some possible defects in the weld and their probable causes are:

1. Bead too narrow–usually indicates an excessive rate of welding speed.
2. Bead too wide–usually indicates too slow a rate of welding speed.
3. Weld contamination–indicated by a black deposit on the weld and caused by the electrode coming in contact with the weld metal.
4. Oxidation of the weld–caused by an insufficient supply of gas.

Magnesium Alloys

TYPES THAT CAN BE WELDED.–Magnesium alloys in virtually all forms can be successfully welded by the GTA welding process without the use of flux. Since this method requires no flux, all types of joints commonly employed on steel can be used on magnesium.

There are, however, some types of magnesium alloys which have poor weldability and are welded only when emergency repairs are necessary. In Table 10-3 the relative weldability of the standard magnesium alloys is summarized briefly. These weldability ratings are very general, since design, fabrication, and serviceability factors dictate the choice of alloy.

CURRENT REQUIREMENTS.–Both direct-current reverse polarity and alternating current with high-frequency stabilization can be used for GTA welding of magnesium alloys. The selection of either a-c or d-c power for welding magnesium alloys is largely dependent upon the thickness of the material to be welded.

Direct-current reverse polarity is suitable for thin materials. On heavier sections, multipass welding is required in most cases due to shallow penetration. Alternating current with high-frequency stabilization is recommended for the welding of magnesium greater than 3/16 inch in thickness. Table 10-4 contains the general operating data for magnesium.

TORCH ADJUSTMENT.–The proper size electrode and corresponding gas cup is determined by the thickness of the material to be welded. The electrode extension should be the same as that previously given for aluminum and aluminum alloys.

SELECTION OF FILLER ROD.–Magnesium alloy filler rod is used and should be of the same chemical composition as the material being welded. It is necessary to use the recommended filler rod for best results. Filler rod is available in a variety of alloys and diameters. Select the correct diameter rod according to the thickness of the material to be welded.

PREPARATION OF METAL.–Cleaning of magnesium is necessary before welding, and can be accomplished by either chemical or mechanical means. For chemical cleaning, a solution of chromic acid and sodium nitrate can be used. Mechanical cleaning can be accomplished with steel wool, abrasive cloth, or a power-operated wire brush. Edges to be welded should be smooth and free from loose pieces or pits which might contain any contamination such as oil, grease, or dirt.

WELDING PROCEDURE.–The same method recommended for starting and stopping the arc previously discussed in the section on aluminum can be used on magnesium The average arc length should be 1/8 inch when using helium and 1/16 inch or less when using argon. A short arc length must be used to produce a bright, shiny weld. Longer arcs will leave the weld surface dark and cloudy in appearance. To obtain maximum penetration with a-c power, the electrode should be flush or slightly below the surface of the work. Accidental touching of the surface with the electrode will not tend to cause it to stick as in the welding of other metals.

The torch should be held with the electrode perpendicular to the work and the filler rod as nearly parallel with the weld surface as possible. The weld should progress in a straight line along the weld seam at a uniform rate of speed so that an even bead is deposited. A weaving or rotary motion is not recommended.

The filler rod can be fed either continuously or intermittently. To avoid oxidation, the rod should not be withdrawn from the gas shield during welding. The end of the rod should touch the leading edge of the puddle. As the torch is moved along, small bits of the rod melt off. No dipping motion of the rod is necessary. With alternating current in welding magnesium it is desirable to start and stop the arc with a torch

Table 10-3.—Relative weldability of magnesium alloys

Alloy	Form	Arc welding	Remarks
AZ91C	Sand castings.	B	Welding used for repairs and to wrought products.
AZ92A	Sand and permanent mold castings.	C	Welding used chiefly for repairs.
AZ63A	Sand and permanent mold castings.	D	Welding used chiefly for repairs.
AZ81A	Sand and permanent mold castings.	B	Welding used for repairs and to wrought products.
EK30A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
EK41A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
EZ33A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
HK31A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
HZ32A	Sand and permanent mold castings.	B	Welding used chiefly for repairs and to wrought products.
AZ91A & AZ91B	Die castings.	E	Emergency repair welding only due to porosity.
AZ31B	Extrusions. Sheet.	A A	
AZ61A	Extrusions.	A	
M1A	Extrusions.	A	
AZ80A	Extrusions.	B	
ZK60A	Extrusions.	E	Limited weldability.
HK31A	Sheet and plate.	A	Excellent welding characteristics.

A—Excellent B—Good C—Fair D—Poor E—Very Poor

Table 10-4.–Data for GTA welding of magnesium

Material thickness (inches)	Number of passes	Welding current* in amperes		Electrode diameter (inches)		Welding rod diameter (inches)	Gas flow (cu ft/min)	
		AZ31B	M1A	a-c	d-c		Argon	Helium
0.040	1	35	45	3/32	3/32	1/8	0.2	0.4
0.064	1	50	60	3/32	1/8	1/8	0.2	0.4
0.081	1	65	80	1/8	1/8	1/8	0.2	0.4
0.102	1	85	100	1/8	3/16	1/8	0.3	0.5
0.128	1	100	115	1/8	3/16	5/32	0.3	0.6
0.188	1	140	160	3/16	5/16	5/32	0.3	0.6
0.188	2	100	100	1/8	3/16	5/32	0.3	0.6
0.250	1	180	200	3/16	3/8	3/16	0.3	0.8
0.250	2	115	125	1/8	1/4	5/32	0.3	0.6
0.375	1	250	270	3/16	—	3/16	0.4	0.8
0.375	2	140	160	3/16	5/16	3/16	0.3	0.8
0.500	2	310	330	1/4	—	3/16	0.4	0.8
0.750	2	420	450	5/16	—	1/4	0.6	1.2

*Current values given for welding with a backing plate and for making fillet welds. Slightly lower current values used for welding without a backing plate and for making corner or edge joints.

switch or open foot switch to prevent oxidation caused by drawing a long arc.

STRESS RELIEVING.–After welding, magnesium should be stress relieved. The temperature for stress relieving varies from 265° to 500° F., depending on the alloy. The soak time also varies from 15 minutes to 1 hour, depending on the alloy. When stress relieving, avoid overheating.

INSPECTION OF WELDS.–All welds should be inspected for penetration and defects. Improper penetration is indicated by a fine line on the reverse side of the weld. This condition can be prevented by slightly beveling the underside of the pieces to be welded. The bevel will let molten weld metal float away oxides formed by heat as it flows down between the sheets.

If cracks appear at the ends of a weld, try preventing recurrence by butting pieces of the same material as that being welded against each end of the joint, clamping them in place until the weld is completed.

Corrosion-Resistant (Stainless) Steel

The wrought stainless steels are of three principal types: austenitic, martensitic, and ferritic. In aircraft work, the AMS will not be concerned with the martensitic and ferritic steels; therefore, the discussion here is limited to the austenitic types.

Austenitic steels are used extensively in aircraft where strength or resistance to corrosion at high temperatures is required. Austenitic steels contain both chromium and nickel and are nonmagnetic. The minimum content of chromium is 16 percent and of nickel, 7 percent. The 18 percent chromium and 8 percent nickel composition is the most popular example of this class of steels. Types 302, 303, 304, 316, 321, and 347 are probably the most extensively used 18-8 steels.

All of the above stainless steels can be satisfactorily welded by the GTA process. The one serious difficulty encountered is intergranular corrosion of the metal in or alongside the weld in certain of these steels.

When an 18-8 stainless steel with more than 0.08 percent carbon is heated between 1,000° and 1,500° F, the excess carbon is precipitated or segregated out of solution and deposited along the grain boundaries in the form of carbides. These carbides are less resistant to corrosion than is the parent metal.

In making a weld, the metal deposited and the joint itself are heated to the melting or fusing temperature, which is approximately 2,690° F, while the body of the work remains cold. Hence, there is a zone parallel to and near the weld which is heated between 1,000° and 1,500° F. It is in this area that carbides are precipitated. This region may be wide or narrow; near or some distance from the weld, depending upon the type of joint and method of welding. If welding is rapid, the zone will be narrow and close to the weld; if slow, it will be wide and farther away.

This carbide can be put into solution again by heating to a temperature of approximately 1,900° F or higher and cooling fast through the critical range. Table 10-5 lists the recommended postweld heat treatments for the most commonly used austenitic steels. It should be noted that alloys 304L, 316L, 321, and 347 require no postweld treatment. Alloys 304L and 316L have a lowered carbon content (0.03 percent maximum), alloy 321 has titanium added, and alloy 347 has columbium added. When either of these procedures is employed, the steel is virtually free from intergranular attack.

Table 10-5.—Recommended postweld heat treatments for austenitic stainless steels

AISI Type	Recommended heat treatment
301 302	Cool rapidly from 1,950° – 2,100° F when corrosion conditions are moderate to severe.
304	Cool rapidly from 1,850° – 2,000° F only when corrosion conditions are severe.
304L	Not required for corrosion resistance.
316	Cool rapidly from 1,950° – 2,100° F only when corrosion conditions are severe.
316L	Not required for corrosion resistance.
321, 347	Not required for corrosion resistance.

CURRENT REQUIREMENTS.–Either direct-current straight polarity or high-frequency stabilized alternating current may be used in welding stainless steels by the GTA process. Slightly greater penetration and welding speed can be obtained with direct current, and high-frequency alternating current has a tendency to cause hot tearing or stress cracks in or near the weld. Direct-current straight polarity is therefore considered first preference. Table 10-6 lists the general operating data for welding the austenitic stainless steels.

TORCH ADJUSTMENT.–The proper size electrode and corresponding gas cup is determined by the thickness of the material to be welded. The electrode should extend about 1/8 inch below the gas cup in most applications. It is important to select the correct size as it is difficult to start and maintain the arc with an oversized electrode.

Table 10-6.–General operating data for stainless steels

Stainless Steel				
Thickness (inch)	Current range (amperes)	Argon flow (cubic feet per hour)	Rod size (inch) (where required)	Arc speed (inches per minute)
0.025	20-40	10	1/32	15-40
0.031	20-40	10	1/32	15-40
0.0375	50-130	10	1/16	15-40
0.050	80-165	10	1/16	15-40
0.0625	90-170	10	1/16	15-40
0.078	125-200	10	3/32	15-40
0.109	140-250	10	3/32	10-35
0.125	150-275	10	1/8	10-30
0.195	100-225	10	1/8	-----
0.250	400-500	10	3/16	12-20
0.375	400-500	10	3/16	*7-14
0.500				

* 2 passes.

SELECTION OF FILLER ROD.–Filler rods for general-purpose welding usually have the same composition as the base metal. Strips cut from parent metal may be used in some cases.

For maximum strength and corrosion resistance, a special type filler rod must be used. Detail information on these special types of filler rods can be found in Specification MIL-R-5031B.

PREPARATION OF METAL.–As with all other materials to be welded with this process, corrosion-resistant steel must be clean. Parts to be welded must be free from oil, grease, or dirt. The surface to be welded may be cleaned either by chemical or mechanical means as previously discussed in this chapter.

WELDING PROCEDURE.–After starting the arc, the torch should be held at an angle of approximately 75 degrees to the work to run the bead. When filler rod is used, it should be held at an angle of approximately 10 degrees to the work. The length of the arc should be approximately 1/8 inch.

The procedure for manipulating the torch is basically the same as that used for other materials. The puddle is developed and the rod is dipped rapidly in and out of the forward edge of the puddle. Care must be taken not to pull the filler rod too far from the puddle. A cold filler rod chills the puddle and makes it difficult to maintain. Dipping in and out of the puddle rapidly will assure the addition of filler metal at a uniform rate to form a weld with good contour.

WELD-BACKUP.–For GTA welding applications on corrosion-resisting steels, the joint should be backed up. On light gage materials, backing is used to protect the underside of the weld from atmospheric contamination which results in poor surface appearance. On heavier materials, it prevents the weld puddle from dropping through by drawing away some of the heat.

Some of the materials used for weld-backup are: metal backup bars; gas shielding; a combination of metal backup bars and gas shielding; and fluxes.

On applications where the final weld composition must conform to rigid specifications, extra care must be taken to exclude all atmospheric oxygen from the underside of the weld. There are a number of gases and methods of applying them that will give 100 percent protection of the weld zone.

INSPECTION OF WELD.–Good weld penetration is indicated by either the oxide deposit (color bands) or a small smooth bead on the underside of the work. A finished weld should have a regular bead pattern and may require some cleaning. Cleaning can usually be accomplished by wire brushing.

Titanium

Titanium and some titanium alloys can be joined by gas shielded arc welding and resistance welding. Oxyacetylene and manual shielded metal arc welding are impractical.

It is very important in GTA welding titanium that the root of the titanium weld, as well as the face of the weld, be protected from the air. This is accomplished with gas backup shielding or, in certain cases, by placing a water-cooled copper bar flush against the underside of the weld joint.

CURRENT REQUIREMENTS.–The recommended power supply for GTA welding titanium is direct current straight polarity. The negative electrode operates cooler than the positive weld joint, enabling a small electrode to carry high current densities. This results in the deepest weld penetration and narrowest bead width.

GTA welding with direct-current reverse polarity requires greater operator skill and generally is not recommended because the hotter electrode increases the possibility for tungsten contamination of the weld. A larger electrode operating at lower current would run cooler, but would produce wide weld beads at the expense of penetration.

High-frequency stabilized alternating current has been used in some cases with apparently similar penetration and strength as that obtained with d-c power, but the uniformity of the welds has never been good.

The GTA process is the most widely used method for welding titanium. It is used almost exclusively on sheet materials up to thicknesses near 0.125 inch. It also can be employed successfully over a wide range of the heavier plate sizes.

GTA welding can be accomplished with or without filler materials. The decision to use filler is based on the metal thickness and joint fit-up. With good fit-up, filler is generally required for thicknesses near 0.090 inch to avoid undercutting adjacent to the weld bead. With less satisfactory joint fit-up, filler may be required in lighter gages to avoid burn-through as well as undercutting.

Thoriated tungsten electrodes are recommended for welding titanium. These electrodes produce greater arc stability, exhibit superior arc starting characteristics, and operate cooler for a given current density than pure tungsten electrodes. Cooler operating temperatures permit use of smaller electrodes and greater freedom from weld metal contamination.

Proper selection of electrode size is based on the smallest diameter which can carry the required current for a given joint.

This concentrates the heat to insure weld penetration, arc stability, narrow weld beads, and high welding speeds. Generally, a 1/16-inch diameter electrode is satisfactory for the entire range of titanium sheet gages. Centerless ground electrodes give the best arc stability, and tapering the points improves arc-starting characteristics as well as control of the physical dimensions or spread of the arc. Thoriated electrodes retain their points longer than the other types.

The electrode should be centered in the nozzle to provide the arc zone with uniform gas shielding. Extension of the electrode below the nozzle is generally 1-1/2 times the electrode diameter for butt-welded joints. In the case of fillet welds, the electrode is sometimes extended as much as 1/2 inch below the nozzle to retain the larger diameter nozzle required for titanium.

GAS SHIELDING.–The gas for shielding titanium may be either helium or argon, a combination of both, or a mixture of both. Helium-shielded arcs operate at somewhat higher arc voltages for a given weld current and are hotter than argon-shielded arcs. This produces greater weld penetration and allows faster welding speeds. However, the hotter helium-shielded arc is also less stable than the argon arc, requiring more operator skill and more accurately controlled weld settings, as well as better joint fit-up to prevent burn-through and weld irregularity.

Argon is generally preferred as the gas in GTA welding. Speed is not the important factor, and more can be gained with a stable arc and the heavier blanket of shielding gas.

Combinations of the two gases involve using argon at the face of the weld and helium on the underside to take advantage of their respective densities and arc characteristics. Mixtures of the two gases are sometimes used for the primary shielding from the nozzle to produce arc characteristics of both helium and argon.

WELDING PROCEDURE.–Although proper equipment is the first prerequisite for the successful welding of titanium, the use of proper techniques is of primary importance. These techniques consist of observing certain precautions which would be recognized as optimum practice for the GTA welding of any metal, and include good joint fit-up, clean weld surfaces, and complete protection from atmospheric contamination regardless of the type of titanium welding performed. Additional techniques are dependent upon the particular application and involve the proper selection of joint design, shielding setup, electrode type, and weld machine settings such as current, welding speed, filler wire feed, arc length, and gas flow rate.

Recommended settings for welded titanium sheet without filler are listed in Table 10-7. More detailed data is available from such leading fabricators of titanium products as RemCru, Incorporated, and Titanium Metals Corporation of America, or from the Titanium Metallurgical Laboratory, Columbus, Ohio.

GAS METAL-ARC WELDING

Gas metal-arc (GMA) welding is also known as micro-wire welding. It uses a direct current and a gas shield of argon, helium, or carbon dioxide (CO_2). A small diameter wire serves both as electrode and filler metal and is fed continuously and automatically from a spool or reel through a flexible cable to the torch or electrode holder. GMA welding equipment is designed to initiate gas coverage and automatically feed the electrode into the weld area when the arc is struck. A welding pool is formed immediately when the arc is established. Welding progresses by moving the welding gun along the line of the joint at a rate to build up a bead of the desired dimensions. The electrode and weld pool are protected from oxidation by the shield of gas during welding. No flux is required.

GMA WELDING EQUIPMENT

There are numerous types and models of GMA welding equipment used in the Navy; basically, they all have the same requirements. Each must have a source of DCRP welding current, a wire feed unit for feeding the wire filler metal, a control unit which controls the automatic feed of the wire filler metal and shielding gas, and a welding gun for directing the wire filler metal and shielding gas to the weld area. Figure 10-6 illustrates GMA welding equipment.

The power source or welding machine must be the direct-current, "Constant Voltage" (CV) type; however, it can be a direct-current (d-c) rectifier or a motor or engine-driven generator. The output welding power of this type machine has essentially the same voltage regardless of the welding current. Output voltage is regulated by a rheostat on the welding machine. The range is 15-40 volts, depending on the type of shielding gas used. Open circuit voltage (while not welding) and arc voltage (while welding) are indicated on the machine's voltmeter. The constant voltage machine has no current control; therefore, it cannot be used for manual shielded metal arc welding.

The special wire feeder and the constant voltage machine form the heart of this process. A fixed relationship exists between the rate of electrode burnoff and welding current. At a given wire feed speed rate the machine will produce the current required to maintain the arc; consequently, the electrode wire feed rate

Table 10-7.—Typical data for GTA welding titanium

Tungsten arc without filler			
Metal thickness	0.030	0.060	0.090
Electrode diameter	1/16	1/16	1/16-1/32
Voltage	10	10	12
Amperes	25-30	90-100	190-200
Nozzle (ID)	9/16-5/8	9/16-5/8	5/8-3/4
Primary shield (cfh, argon)	15	15	20
Trailing shield (cfh, argon)	20	30	50
Backup shield (cfh, helium)	4	4	5
Backup material	Copper or steel	Copper or steel	Copper or steel
Electrode travel (ipm)	10	10	10
Power supply	DCSP	DCSP	DCSP

determines the welding current. Wire feed speed is set by the control knob on the wire feeder. The welding current is indicated on the machine's ammeter (while welding) and ranges from approximately 100-800 amperes, depending on the diameter size of the electrode. (See table 10-8.) Direct current with reverse polarity (DCRP) is used for this process.

The reverse polarity arc supplies heat to melt the consumable filler wire and the work-piece. The arc also breaks up the surface oxide on the workpiece. This cleaning action is due to the electrical characteristics of the DCRP arc. Arc action is not intermittent as in a-c GTA welding, but is continuous because there is no change in current direction using d-c GMA welding.

FILLER METAL

The GMA welding process uses a consumable electrode wire ranging in size from 0.030 to 1/8 inch. The sizes 0.030, 0.035, and 0.045 are referred to as microwire. The wire is solid and bare, except for a very thin copper coating on the surface to prevent corrosion. It contains deoxidizers to help clean the weld metal and to produce sound, solid welds. The wire should be carefully selected to assure the composition of the wire will have similar mechanical properties as the base metal.

The distance from the contact tip to the work is called STICKOUT. This distance is controlled by the weldor and should be 1/4 to 3/8 inch.

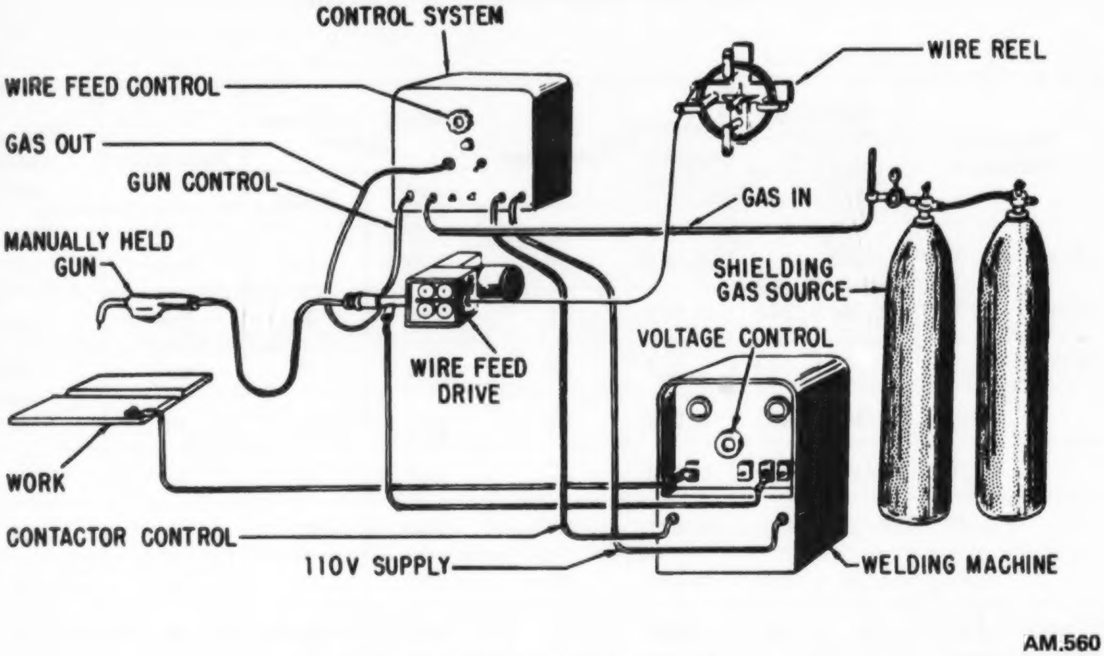

Figure 10-6.–GMA welding equipment.

The contact tip is recessed from 0 to 1/8 inch inside the cup or nozzle.

Special attention must be given to see that the wire used is clean. Unsound welds result from the use of wire which has been contaminated by oil, grease, dust, or shop fumes. Best welding results are obtained by using wire which has just been taken out of its carton. Wire should be stored in a hot locker or in a warm dry area, and should be kept covered. If welding is stopped for any length of time, remove the wire and place it in the original carton to prevent possible contamination.

SHIELDING GAS

The GMA welding gun deposits molten filler metal where directed on the workpiece. The gas shields the arc and weld pool while the filler wire is being melted and transferred in spray or droplet form to the pool. Another purpose of the gas shield is to provide a more easily ionized path than air.

Helium, argon, or mixtures of the two are suitable for GMA welding of aluminum and stainless steel. At any given current, the helium shielded arc has a higher voltage than the argon arc. A smoother, more stable arc is obtained with argon.

Pure argon is used most widely on plates less than 3/4 inch thick. Combinations of argon and helium are often employed for welding heavy plate, particularly for out-of-position welding, to obtain the "hotter arc" characteristics of helium with the stabilizing effects of argon. Mixtures of 75-percent helium and 25-percent argon are commercially available. Other gas mixtures, for example, 60-percent helium and 40-percent argon, are mixed by combining flows from separate tanks of helium and argon. Helium additions of over 10 percent markedly change the arc characteristics.

Carbon dioxide (CO_2) is suitable for GMA welding of mild steel. Because of carbon dioxide's (welding grade) low moisture content, its flow rate must be between 25 and 50 cubic feet per hour (cfh). In order to maintain this gas flow rate it might be necessary to manifold two cylinders together.

The outstanding features of the CO_2 process are: (1) higher welding speed, (2) high metal

Table 10-8.—Ampere settings for GMA welding

Material thickness	Electrode		Deposit approx. lb/ft	CO_2 Gas Flow cfh	Welding conditions DCRP		Reactance	Travel speed ipm
	Size in.	Feed ipm			Amps.	Volts		
18 Ga. - 0.050"	0.045	360	0.010	35	300	26	Yes	190
16 Ga. - 0.062"	0.045	360	0.013	35	325	26	Yes	150
14 Ga. - 0.078"	0.045	360	0.017	35	325	27	Yes	130
1/8"	1/16	200	0.026	35	380	30	No	80
3/16"	1/16	260	0.036	35	425	31	No	75
1/4"	3/32	150	0.077	35	500	32	No	45
3/8"	3/32	205	0.189	35	550	34	No	25
1/2"	1/8	160	0.294	35	625	36	No	23
5/8"	1/8	175	0.411	35	675	36	No	18

deposition rates, (3) deep penetration, (4) greater production.

The flow of gas necessary for good quality GMA welding depends upon the gas used, welding current, diameter of gun nozzle, joint design, welding position, speed of welding, and freedom from draft in the welding area. This last factor can affect gas usage and weld quality considerably, so it is recommended that the welding area be essentially draft-free. When welding in the field, suitable shielding with tarpaulin or other type of windbreak should be provided to prevent natural air currents from interferring with the gas flow.

GMA WELDING TECHNIQUES

Before starting to weld with GMA equipment, be sure that all controls are properly adjusted, that all connections are correctly made, and that all safety precautions are being observed. Wear protective clothing, including a helmet with suitable filter lens. Support the weight of the welding cable and gas hose across your shoulder to insure free movement of the welding gun. Hold the gun close to, but not touching, the workpiece. Lower your helmet and squeeze the trigger on the gun. Squeezing the trigger starts the flow of shielding gas and energizes the welding circuit. The wire-feed motor is not energized until the wire electrode comes in contact with the workpiece, Move the gun toward the work, touching the wire electrode to the work with a sidewise scratching motion as illustrated in view A of Figure 10-7. To prevent sticking, it is necessary to pull the gun back quickly, about 1/2 inch, the instant contact is made between the wire electrode and the workpiece. The arc will strike as soon as contact is made and the wire-feed motor will feed the wire automatically as long as the trigger is held.

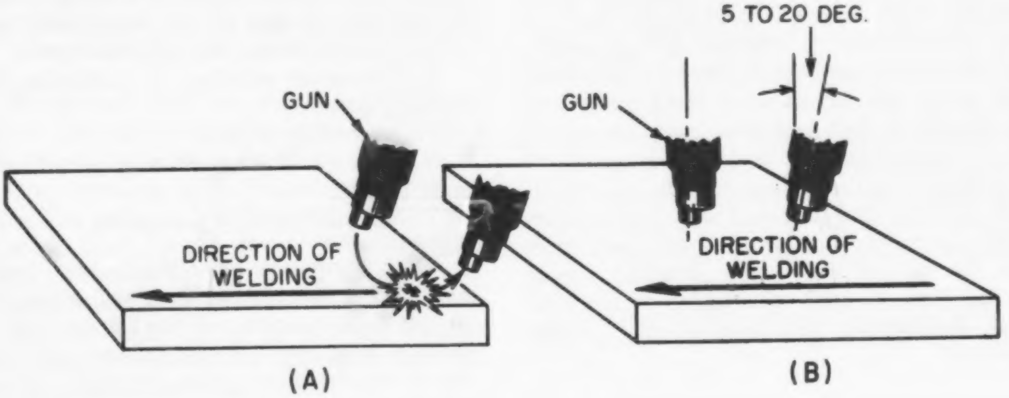

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Figure 10-7.—Gas metal-arc welding. (A) Striking the arc; (B) gun angle.

To break the arc, just release the trigger. This breaks the welding circuit and also deenergizes the wire-feed motor. If the wire electrode sticks to the work when striking the arc, or at any time during welding, release the trigger and clip the wire with a pair of pliers or side cutters.

A properly established arc has a soft, sizzling sound. The arc itself is about 1/4 inch long, or about one-half the distance between the gun nozzle and the work. Adjustment of the wire-feed control dial or the welding machine itself is necessary when the arc does not sound right. For example, a loud, crackling sound indicates that the arc is too short and that wire-feed speed is too fast. Correct this by moving the wire-feed dial slightly counterclockwise. This decreases wire-feed speed and increases arc length. A clockwise movement of the dial has the opposite effect. With experience, you will soon be able to recognize the sound of the proper length of arc to use.

Welding is accomplished by use of the forehand technique. The gun should be held at an angle of 5 to 20 degrees from the vertical position, as illustrated in view B of Figure 10-7. For a right-handed person, the direction of welding is from right to left. The forehand technique provides the best coverage of shielding gas to the weld area, and the operator has a better view of the weld joint. Left-handed persons hold the gun in the same position relative to the surface of the base metal, but the direction of welding is from left to right.

After you have gained some skill in striking and establishing an arc and in adjusting the wire feed and welding current to obtain the proper arc characteristics, you should learn to run a bead. To run a practice bead, select the proper current setting, gas flow, and correct size filler wire; then, proceed as follows:

1. Hold the gun in the proper position, close to but not touching the surface of the work, and squeeze the trigger.
2. Lower your welding helmet and strike the arc.
3. Hold the gun at the starting point until a puddle forms.
4. As soon as you see a puddle, move the gun forward steadily at a rate that permits the work and the electrode to melt at the same time. Keep the arc in the pool of weld metal. Do not direct it into the base metal. A thin, irregular bead will result if you move forward too rapidly. Undercutting may result if you move the gun forward too slowly. A good bead is uniform in width and height, the ripple is uniform, and there is no overlap or undercut at the edges.

Instead of moving the gun along the line of weld with a steady forward motion, some operators prefer to run a bead with a reciprocating technique like that shown in Figure 10-8. With this technique, strike the arc and then slowly move the gun forward along the line of weld about 1/2 inch and then back about 1/4 inch. Continue this 1/2 inch forward and 1/4 inch backward motion along the line of weld. If a wide bead is desired, use a side weave. Here, the gun is moved uniformly back and forth across the line of weld while steadily moving along the line of weld. The width of the bead desired determines the amount of sidewise movement.

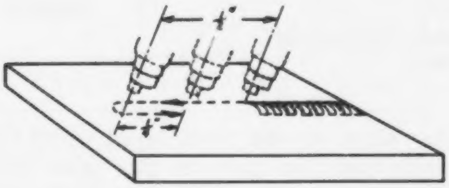

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Figure 10-8.—Reciprocating technique for gas metal-arc welding.

Although GMA welding does not require the use of a flux, it does require that the base metal be clean. Aluminum and aluminum alloys should be cleaned with an approved compound, or with a rotary stainless steel wire brush. If grease is present, it should be removed with a solvent prior to cleaning with a compound. Rotary stainless steel wire brushes which have picked up grease should be cleaned with a solvent before they are used to clean aluminum for welding.

Once you get the feel of welding with GMA equipment, you will probably find that the techniques are less difficult to master than any of the other welding procedures. There are some pitfalls, however. Porous welds may result from the following causes:

1. Low arc voltage (less than 26 volts).
2. Low welding current.
3. Inadequate shielding gas flow resulting from a low cylinder pressure, from restrictions in the gas passages of the equipment, or from improper adjustment of the flowmeter.
4. Excessive weaving or whipping of the welding gun.
5. Poor fitup of parts.
6. Improperly cleaned base metal, or dirty welding wire.
7. Nonuniform wire-feed speed.

Welder fatigue is often the cause of poor weld quality and low output. You will learn that the quality and quantity of work improves as you learn to weld comfortably. Out-of-position welding is usually more awkward than flat position welding; therefore, arrange the work for flat position welding whenever possible for economy and quality.

Satisfactory weld results also depend on good maintenance of the GMA equipment. Maintenance procedures are outlined in the manufacturer's technical manual furnished with the equipment.

SAFETY PRECAUTIONS

Safety must be observed in GTA and GMA welding as in any other welding process. The following are general precautions that should be observed:

1. The welding area must be properly ventilated without excessive drafts affecting the welding arc and shielding gas. Radiation from the arc causes instantaneous decomposition of chlorinated solvents, such as perchloroethylene, trichloroethylene, and methyl chloroform, into highly toxic phosgene gas and other irritating products. Welding should not be done in any area where fumes from such solvents are present.
2. The voltage required for operating GTA and GMA welding equipment can cause severe or fatal injuries, so do not work on any wiring in an energized circuit. The deck where welding is being done must be dry.
3. Welding transformers or rectifiers must have a power ground so that welders cannot get a shock should stray current develop.
4. Do not lay the torch on the work or work table. Hang it up in a safe place so the electrode is not touching metal which may be grounded.

5. Do not change a tungsten electrode before it has cooled or while the transformer switch is in the "on" position. Do not change spools of filler wire while the generator or rectifier is "on."

6. Do not use defective welding cable. If any of the connections are operating hot, a poor electrical connection may exist.

7. Use a welding helmet when looking at the arc. Use the correct shade of lens. If your eyes become irritated, see the doctor immediately. If not treated promptly, the irritation caused by burning rays of the arc become very painful and feels like hot sand in the eyes. There are eye drops which the doctor will give you that will relieve unnecessary suffering.

8. Wear suitable clothing as protection from the spatter or molten particles and to shield the body from rays of the arc.

9. Do not strike an arc on a compressed gas cylinder.

10. Do not weld in the vicinity of flammable or combustible materials. Degreasing with alcohol or other flammable solvents in an improperly ventilated welding area creates a fire hazard.

11. Do not weld on containers which have held combustible or flammable materials without first exercising the proper precautions.

12. Do not weld in confined spaces without adequate ventilation or individual respiratory equipment. Do not weld on workpieces without wiping the degreasing solvent off.

13. Mark metal "HOT" for aluminum does not change color when heated.

14. Do not chip or grind without safety goggles.

15. Do not move individual cylinders unless valve protection cap, where provided, is in place and tight.

16. Do not drop or abuse cylinders in any way.

17. Make certain that cylinders are well fastened in their stations so that they will not fall.

18. Do not use a hammer or wrench to open cylinder valves.

19. Never force connections which do not fit.

20. Never tamper with cylinder safety devices.

21. Always protect hose and welding cable from being trampled or run over. Avoid tangles and kinks. Do not leave the hose and cable so they can trip people.

22. Protect the hose, cable, and cylinders from flying sparks, hot metal, hot objects and open flame.

23. Do not allow hose to come in contact with oil or grease; these rot the rubber and are a hazard.

24. Be sure that the connections between the regulators, adaptors and cylinder valves are gas tight. Test with soapy water under gas pressure.

25. When welding is to be stopped for an extended length of time, release the pressure adjusting screws of the regulators.

26. When welding is to be stopped for a long time, close the cylinder valves and then release all gas pressure from the regulators and hose.

27. If the equipment is to be taken down, close the cylinder valves, make certain that all gas pressures are released from the regulators and hose, and see that the pressure adjusting screws are turned in the counterclockwise direction.

28. Use paints which have low indices of untraviolet reflection for GTA or GMA welding areas. A rubber-base, dead flat green or blue paint is suitable.

CHAPTER 11

NONMETALLIC MATERIALS

As you already know, there are many nonmetallic materials used in aircraft construction, the most common materials being plastic, rubber, fiberglass, paint, sealants, etc. At the E-6 and E-7 level the AMS is concerned with the practical aspects of repairing leaks in integral fuel tanks and/or knowing the procedures used in repairing bladder and selfsealing fuel cells.

In this chapter we will discuss the types, construction, maintenance, repair, and handling of fuel cells, both integral and rubber, and deicer boots. Also included in this chapter is a section on sealing compounds, their purpose and use, and the procedures and tools used when repairing fuel cells and/or resealing aircraft structures.

FUEL CELLS

Included among the various types of fuel cells used on naval aircraft are self-sealing cells, bladder type cells, and integral cells. Self-sealing cells and bladder type cells are made of rubber and are removable from the aircraft. Integral cells form a part of the aircraft structure and are therefore not removable.

During World War II, all U.S. combat type aircraft were equipped with self-sealing fuel cells, while most noncombat aircraft used either bladder type or integral type cells. With the development of the high-performance jet aircraft, manufacturers have gradually switched to the bladder and integral types in order to increase the combat range; however, some aircraft still in service are equipped with self-sealing fuel cells.

Since the AMS is concerned with the repair of bladder and self-sealing fuel cells, it is imperative that he be familiar with the construction features of the various types of fuel cells, and have a clear understanding of the repair procedures and limitations for each type.

SELF-SEALING FUEL CELLS

A self-sealing cell is a fuel or oil container which automatically seals holes or injuries caused during combat operations. A self-sealing cell is not bullet proof, but is merely puncture sealing. As illustrated in Figure 11-1, the bullet penetrates the outside wall of the cell and the sticky, elastic sealing material surrounds the bullet. As the bullet passes through the cell wall into the cell, the sealant springs together quickly and closes the hole. At this time some of the fuel in the tank comes in contact with the sealant and makes it swell, completing the seal. In this application, science has used the natural stickiness of rubber and the basic conflict of rubber and petroleum to seal the hole. This sealing action reduces the fire hazard brought about by leaking fuel or oil and keeps the aircraft's fuel or oil intact so the aircraft may continue operating and return to its base.

The most commonly used types of self-sealing fuel cells are the standard construction and the combination bladder and self-sealing cell.

Of the two listed above, the standard construction cell is the most common type. It is a semiflexible cell, made up of numerous plies of material.

The combination bladder and self-sealing cell is made up of two parts. One part is made of bladder type rubber, and the other part is identical to the standard construction cell. This type cell is designed to self-seal holes or injuries

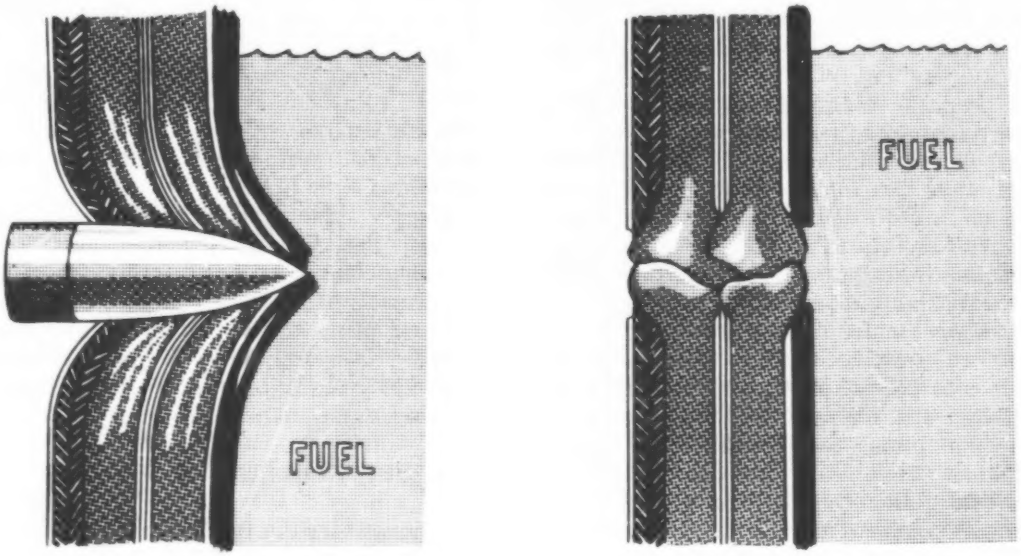

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Figure 11-1.–Bullet sealing action.

in the bottom area and the lower portions of the side areas. The bladder part of the cell is usually restricted to the upper portions. This type cell is also semiflexible.

Self-Sealing Cell (Standard Construction)

There are four primary layers of materials used in the construction of a self-sealing cell–the inner liner, nylon fuel barrier, sealant, and retainer. All self-sealing fuel cells now in service contain these four primary layers of materials. If additional plies are used in the construction of the cell, they will be related to one of the primary plies.

The inner liner material is the material used in the inside of the cell. It is constructed of Buna N synthetic rubber. Its purpose is to contain the fuel and prevent it from coming in contact with the selant, preventing premature swelling or deterioration of the sealant.

NOTE: Buna rubber is a manmade substitude for crude or natural rubber. It is produced from butadiene and sodium and is made in two types, Buna S and Buna N. The Buna S is the most common type of synthetic rubber but is unsuitable for use as inner liner material in fuel cells since the aromatic fuels used in aircraft cause it to swell and eventually dissolve. The Buna N is not affected by aromatic fuels, making it ideal for this application. However, the Buna N is slightly porous, making it necessary to use a nylon barrier to prevent the fuel from contacting the sealant.

The nylon fuel barrier is an unbroken film of nylon. The purpose of the nylon fuel barrier is to prevent the fuel from diffusing farther into the cell. The nylon is applied by brush, swab, or spray in 3 or 4 hot coats to the outer surface of the inner liner during construction.

The sealant material is the next material used in fuel cell construction. It remains dormant in the fuel cell until the cell is ruptured or penetrated by a projectile. When this occurs it is the function of the sealant to seal the ruptured area so that gasoline will not flow through to the exterior of the fuel cell. (See Fig. 11-1.)

The mechanical reaction results from the fact that rubber, both natural and synthetic, will "give" under the shock of impact, thereby limiting damage to a small hole in the fuel cell.

The fuel cell materials will allow the projectile to enter or leave the cell and then will return to their original position. This mechanical reaction is almost instantaneous.

The chemical reaction takes place as soon as gasoline vapors penetrate through the inner liner material and reach the sealant. The sealant, upon contact with gasoline or gasoline vapors, will extend or swell to several times its normal size. This effectively closes the rupture and prevents the gasoline from escaping. The sealant is made from natural gum rubber.

The retainer material is the next material used in fuel cell construction. The purpose of the retainer is to provide strength and support, and to increase the efficiency of the mechanical action by returning the fuel cell to its original shape when punctured. It is made of cotton or nylon cord fabric impregnated with Buna N rubber.

One variation of the standard construction self-sealing fuel cell is shown in Figure 11-2. It is constructed from the four primary materials covered in the preceding paragraphs and consists of the following: An inner liner, nylon fuel barrier, two sealant plies, and three retainer plies.

NOTE: The cords in the first retainer ply run lengthwise of the cell. The cords in the second at a 45-degree angle to the first and the cords in the third at 90-degree angle to the second. The outside is coated with Buna-Vinylite lacquer to protect the cell from spilled gasoline and weathering.

Baffles and internal bulkheads are used inside the cell to help retain the shape of the cell and prevent sloshing of the fuel. They are constructed of square woven fabric impregnated with Buna N rubber.

Flapper valves are fitted to some baffles to control the direction of fuel flow between compartments or interconnecting cells. They are constructed of micarta, bakelite, or aluminum.

These plies, baffles, internal bulkheads, and flapper valves together with the necessary fittings and connections make up a typical standard construction self-sealing fuel cell.

BLADDER TYPE FUEL CELLS

A nonself-sealing fuel cell, commonly called a bladder type cell, is a fuel container which does not self-seal holes or punctures. The advantage of using a bladder fuel cell results from the saving in weight, the comparative simplicity of repair techniques, and the reduced procurement costs over self-sealing fuel cells.

Bladder type cells are usually made of very thin material in order to give minimum possible weight. They require 100 percent support from a smooth cavity. The cell is made slightly larger than the cavity of the aircraft so the weight or

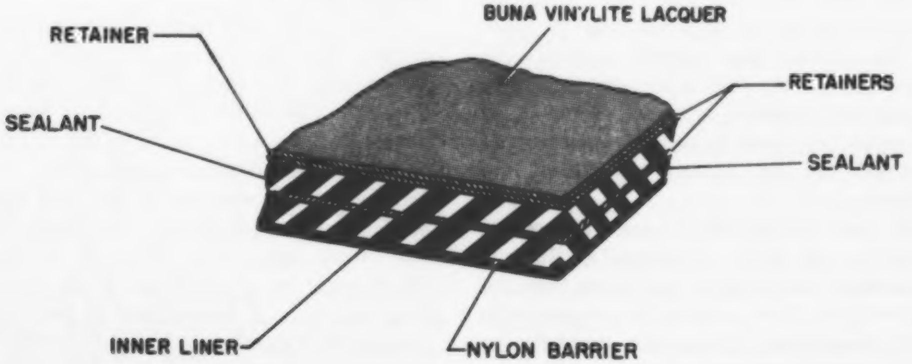

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Figure 11-2.—Self-sealing fuel cell. (Standard construction.)

internal pressure of the fuel is borne by the aircraft structure.

The thinner wall construction increases the fuel capacity over the self-sealing cells, thus increasing the range of the aircraft. For this reason, many of our aircraft that were formerly equipped with self-sealing cells have been changed to bladder type cells.

There are two types of bladder fuel cells–rubber type and nylon type.

Rubber Type Bladder Cells

The rubber type bladder cells are fabricated in the same manner as self-sealing cells in that they have a liner, nylon barrier, and a retainer ply. The sealant layers are omitted. All three plies are placed on the building form as one material in this order–liner, barrier, and retainer. Figure 11-3 illustrates this type construction.

INNER LINER–The inner liner may consist of Buna N rubber, Buna N coated square-woven fabric (cotton or nylon) or Buna N coated cord fabric. The purpose of the inner liner is to contain the fuel and provide protection for the nylon barrier.

NYLON BARRIER–The nylon barrier consists of three to four coats of nylon applied hot by brush, swab, or spray. The purpose of the nylon barrier is to keep fuel from diffusing through the cell wall.

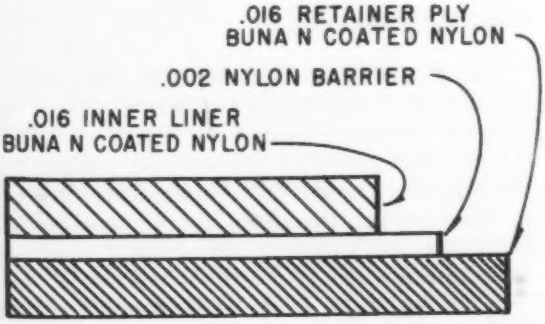

Figure 11-3.–Bladder cell construction.

RETAINER.–The retainer consists of Buna N coated square-woven fabric (cotton or nylon) or cord fabric. The purpose of the retainer ply or plies is to lend strength to the fuel cell and provide protection for the nylon fuel barrier.

Nylon Type Bladder Cell (Pliocel)

Nylon bladder cells differ in construction and material from the Buna N rubber cells. This type cell may be identified by the Goodyear trade name "Pliocel" stenciled on the outside of the cell. The Pliocel construction consists of two layers of nylon woven fabric laminated with three layers of transparent nylon film.

The repair of this type cell must be accomplished by entirely different methods and with different materials. The adhesive and Buna N rubber used with the rubber type bladder cells cannot be used with the nylon type cell.

MAINTENANCE

All fuel cells have been improved a great deal, both in design and workmanship. As a result of these improvements and better maintenance, self-sealing fuel cells no longer have a time limitation upon their service life. Since these cells are made of rubber they require special care and maintenance in order to give long service. General and preventive maintenance along with handling, storage, and repairs are discussed in this section on maintenance of fuel cells.

General Maintenance

When removal of the cells is necessitated by major repairs or other reason, they should be inspected, then reinstalled, provided they are fit for further service in the aircraft. The cells should be removed when signs of leakage appear, when there are rubber particles in the strainer, or if loose seams, loose or cracked fittings or swollen sealant are found. If the cell is considered to be repairable, it should be crated and sent to the nearest fuel cell repair activity.

When a cell that has contained fuel is to remain empty for more than 72 hours, a thin coat of oil, Specification MIL-L-6081, Grade 1010, should be applied to the inner liner. This should be accomplished whether the cell is installed or removed from the aircraft for storage. The oil will act as a temporary plasticizer and will prevent the inner liner from drying out and cracking.

Fuel cells which are to be returned to storage until repairs can be accomplished at a later date should have a coating of oil, Specification MIL-L-6082, Grade 1065, applied to the interior of the cell. The heavier type of oil will act as a preservative over a sustained period. Oil should not be applied to the interior of self-sealing cells which have exposed sealant until the exposed area has been covered with an oil resistant tape. Although complete coverage of the cell interior is necessary, preservative oil should not be allowed to puddle in the bottom of the cell.

All preservation of fuel cells should be done in accordance with the applicable Maintenance Instruction Manual and NavAir 03-10-513, Maintenance Instructions on Self-Sealing and Bladder Type Fuel Cells.

Torque Requirements

One of the main causes of fuel leaks can be attributed to improper torquing of bolts used to secure fittings, door cover plates, and attachments. Overtorquing causes excessive rubber cold flow, warps fitting plates, and in some cases, breaks the metal insert in fittings. Improper torquing sequence results in fuel leaks, therefore, it is important that a set sequence be followed. The aircraft Maintenance Instructions Manual will generally specify torque sequences and techniques. However, when specific instructions are not provided, the general instruction contained in NavAir 03-10-513 should be used.

Preventive Maintenance

Preventive maintenance is very important because of the cost of manufacture and the manhours necessary to remove, replace and repair fuel cells. Some of the items which will prolong the service life of fuel cells are listed as follows:

1. Never allow fuel to spill on the outside of cells. If it should occur, clean cell as soon as possible.
2. Stiffener rods may be easily replaced by coating with soapy water. Never drive them into place or use oil or grease.
3. Never pry on rubber fittings of cells with sharp instruments.
4. Never climb into cells with sharp instruments in your pockets. Be extremely careful not to puncture cell lining. Always remove shoes before getting into a cell, and cover the bottom with cloth while working inside of the cell.
5. Never allow a hot light bulb to rest on the inside of a cell while making repairs or inspection. Be sure always to use safety lights inside of cells.
6. All openings must be covered when the cell is outside of the aircraft.
7. In handling cells during installation, jostle them into position, never pull them by their fittings.
8. Use only the prescribed seam sealing compounds and other authorized materials on fuel cells or permanent damage may result.

HANDLING AND STORAGE

The majority of early failures of fuel cells are caused by improper handling and storage of the cells. The cells are made of rubber; they are not made of metal, plastic, or wood. Each cell is virtually a hand-made item except for the actual curing of the cell. Each individual fitting of the cell is designed for that particular position in which it is placed so as to line up with a like orifice or connection in the aircraft structure. To prevent damage to fuel cells during handling and storage, the following precautions should be observed.

Handling Precautions

Always carry or haul fuel cells. The purpose of carrying or hauling fuel cells is to protect the outside (retainer ply) wall, which serves to support the shape of the cell and protect the self-sealing (sealant) layer underneath it from gasoline spillage; therefore, its cord construction and lacquer coating must be cautiously safeguarded.

Never jostle or carry cells around by their fittings. Such handling may distort or break the metallic ring around the fitting, causing complete failure of the fuel cell. Do not flex cold cells since this will crack the stiffened synthetic rubber. Cells exposed to cold temperature (below 65° F) should be warmed to room temperature before being handled excessively.

Remove cells from shipping containers carefully. Before removing, be sure to detach all carrier straps and hanger fittings. Sufficient man-power should be available to carefully remove the cell from its container.

Never leave a self-sealing fuel cell in a collapsed condition for longer than one hour. The cell should be suported either by its support straps or braced internally. A bladder-type cell may be left collapsed for an indefinite period providing the cell is not walked upon, severely creased, or otherwise abused.

NOTE: Bladder type fuel cells and nylon pliocels are much more delicate than self-sealing cells and require extremely careful handling; otherwise the handling precautions are the same as for self-sealing cells.

Storage Precautions

Cells, whether packaged or not, should be stored as properly as local facilities will permit. Store cells in a room which is cool, clean, dark, dry, and free from constant circulation of air or drafts. Sunlight and heat in the room cause the plasticizing agent to dissipate, resulting in hardening and cracking of the rubber.

Leave fuel cells in the original shipping container until they are actually needed for installation. Cells should be stored so that the oldest cell will be used first.

For long term storage, cells should be placed in wooden boxes, but never stacked to the extent of collapsing the lowest package, or over four high.

Uncrated cells should be individually stored on shelves on the widest and flattest surface that does not have protruding fittings, unless stenciling on the cell indicates otherwise. Do not stack uncrated cells, or allow them to lie around the shop.

Before storing, fuel cells should be clean and free from water or fuel. Cell openings should be sealed with masking tape or other suitable material to prevent dust and dirt from entering the cell. Always leave a small vent hole in one opening so pressure in the cell will always be the same as that of the surrounding atmosphere.

Store cells away from electrical equipment. Electrical equipment produces ozone from oxygen, which rapidly attacks synthetic rubber, causing it to crack much quicker than normal atmospheric oxidation. To retard ozone cracking, or excess oxidation, coat the outside of fittings with Buna-Vinylite lacquer.

NOTE: Ozone is a pungent allotropic form of oxygen found in the atmosphere, formed usually by a silent electrical discharge in air. An example is the pungent odor in the air caused by arcing brushes in an electric motor or generator.

REPAIRS

All repairs made on fuel cells are permanent type repairs. Experience has proven that the time and effort required for making temporary repairs is as great as that necessary for permanent repairs.

Self-Sealing Fuel Cells

A self-sealing fuel cell is "self-sealing but not self-healing." Therefore, any fuel cell which has been ruptured so that fuel is in contact with the sealant material must be repaired as soon as possible. If repairs cannot be accomplished within 72 hours, the cell should be drained of fuel, purged, and preserved.

Because of the special tools and materials required, most self-sealing fuel cells are crated and shipped to Depot activities for repairs. However, detailed information regarding the equipment and materials used in repairing fuel cells and the types of repairs can be found in NavAir 03-10-513.

Bladder Fuel Cells

The effectiveness of bladder fuel cell repair depends largely upon correctly analyzing the injury and using the proper methods and materials. Injuries may vary from minor cuts, which may be repaired easily, to extensive rupture of the cell, making repairs difficult or, in some cases, impractical. The method of repair selected or whether the cell should be repaired at all will depend upon the availability of repair materials, spare cells, and sufficient time to do the work.

Repair work on bladder fuel cells must be accomplished in a warm, dry place. Ideal conditions for work on cells are 70° F to 80° F with a 50 percent humidity. High humidity, especially in combination with a low temperature causes condensation to form on cemented surfaces and prevents adhesion of repair patches.

The fuel cell to be repaired should be placed on a smooth, well-lighted table. It should be positioned so that the repair area will maintain its natural contour if possible. The cell should not contact sharp corners or rough surfaces.

The most common cause of damage to bladder type fuel cells is the hole type damage or injury. This type damage may be caused by dropping tools inside the cell while removing or installing the cell, or chafing caused by rivet heads or other objects in the cell cavity. Damage is also caused by contact with fuel nozzles and other equipment used in fueling the aircraft.

Bladder type fuel cells with damage which extends through the inner liner only may be repaired with a single patch. Cells with damage which is 2 inches or less in diameter and extending through the cell wall should be repaired with an inside and outside patch. Cells with damage which is greater than 2 inches in diameter through the cell wall should be repaired with a double inner and outer patch.

There are two methods of repair used on bladder type fuel cells. The hot cure (vulcanized) method requires heating equipment which is not available in most operating activities. The air cure method described in this chapter may be made very easily if the necessary materials are available.

AIR CURE REPAIR.–When the cell is ready for repairs, the repair area should be buffed approximately 1 3/4 inches in all directions from the damage for a single patch and 2 3/4 inches for damage which requires a double patch. Buffing may be accomplished with clean emery cloth (180 grit) or with a power buffing tool such as the pneumatic drill and emery wheel illustrated in Figure 11-4. Buffing should be heavy enough to remove all gloss, leaving the surface covered with fine scratches. However, care should be exercised to assure that the nylon barrier is not damaged.

CAUTION: Power buffing and grinding will produce large quantities of dust and smoke which are irritating when inhaled. Therefore, buffing and grinding operations should be accomplished in a well ventilated area or while using a respirator.

The patch should be prepared from the recommended nylon sandwich material. It should be large enough to extend 1 1/2 inches in all directions from the edge of the damage. The patch should have a smoothly rounded outline and the edges should be skived (cut on an angle) by tilting the shears instead of cutting straight. The patch should be buffed (as previously described) on the side that will be cemented to the cell.

After the cell and patch have been buffed, clean the buffed area with methyl ethyl ketone (MEK) solvent. As soon as the solvent is dry, apply three thin coats of the specified cement to the patch and the repair area. Each coat should dry approximately 30 minutes before the next coat is applied. The third coat should be allowed to become tacky before placing the coated surfaces together. If the third coat dries out before the coated surfaces can be placed together, the adhesive coated surfaces should be wiped lightly with a cloth moistened with MEK solvent to effect a tacky condition.

NOTE: If the cement is not allowed to dry to the proper stage of tackiness, air bubbles or blisters may form under the patch during the drying process. Sliding or skidding of the patch immediately after application are indications that the cement has not dried to the proper stage.

When the third coat of cement has dried until it is tacky, center the patch over the repair area. Care should be taken to prevent air from being trapped under the patch. The patch should be stitched or rolled down with a roller as illustrated in Figure 11-4.

After the repair has been allowed to set up for approximately 2 hours, inspect the patch for looseness and apply the recommended adhesive to the edges of the repair. Fuel cells repaired in this manner should remain undisturbed for at least 72 hours before installation or being

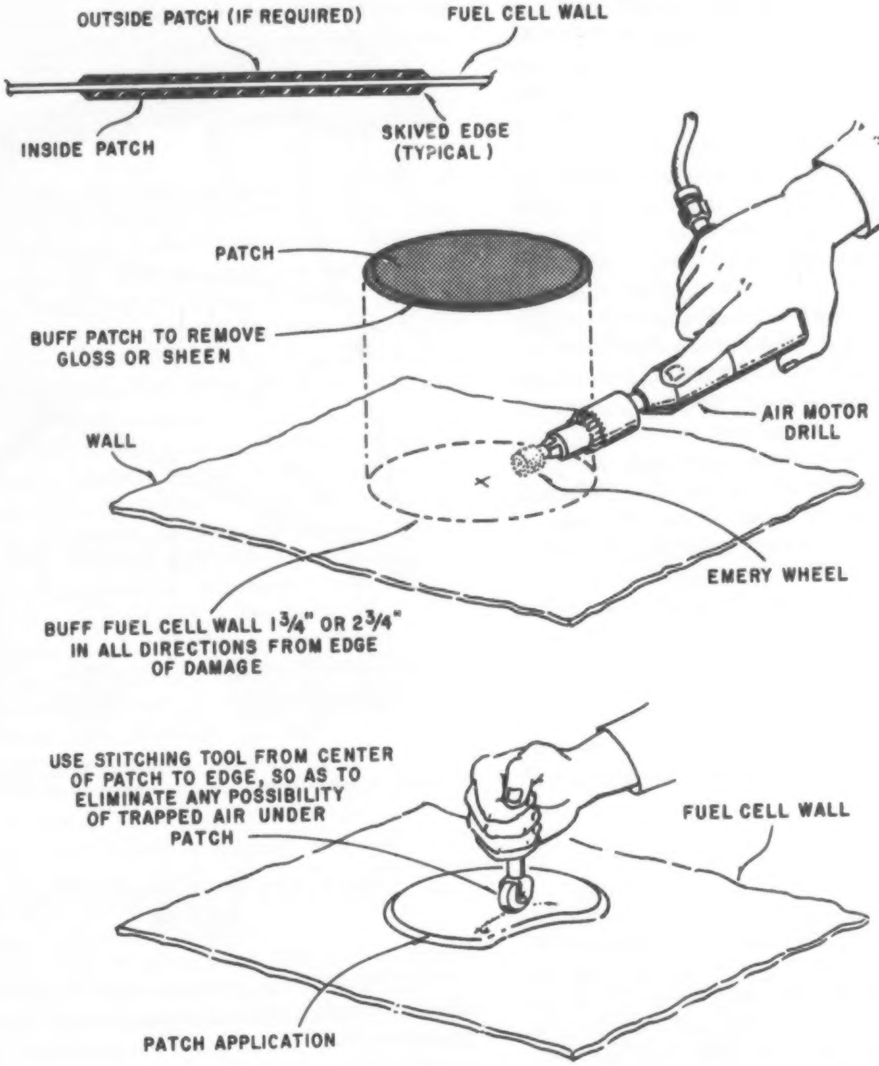
OUTSIDE PATCH (IF REQUIRED)
FUEL CELL WALL
INSIDE PATCH
SKIVED EDGE (TYPICAL)
PATCH
BUFF PATCH TO REMOVE GLOSS OR SHEEN
WALL
AIR MOTOR DRILL
EMERY WHEEL
BUFF FUEL CELL WALL 1¾" OR 2¾" IN ALL DIRECTIONS FROM EDGE OF DAMAGE
USE STITCHING TOOL FROM CENTER OF PATCH TO EDGE, SO AS TO ELIMINATE ANY POSSIBILITY OF TRAPPED AIR UNDER PATCH
FUEL CELL WALL
PATCH APPLICATION

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Figure 11-4.—Bladder cell repair.

subjected to fuel. The repair area should not be flexed for the first 24 hours.

CAUTION: Do not place the cell in any type of heating chamber to accelerate drying. Such action will cause the cell to deteriorate and shrink beyond safe dimensions.

When the repair is on the outside of the cell, two coats of Buna-Vinylite lacquer should be applied to the patch and repair edges after the repair has cured. The first coat should be allowed to dry before applying the second coat.

INTEGRAL FUEL CELLS

Integral fuel cells are usually contained in the wing structure; however, in some aircraft integral fuel cells are built into the fuselage. An integral cell is a part of the aircraft structure which has been built in such a manner that after the seams, structural fasteners, and access doors have been properly sealed, it will hold fuel without leaking. This type construction is usually referred to as a "wet wing."

Usually, the cell area is located between two spars and is capped off on the ends by sealed end ribs. The skin covering may be standard riveted sheet or may be milled from a solid plate of aluminum alloy. These milled skins are usually bolted in place instead of being riveted.

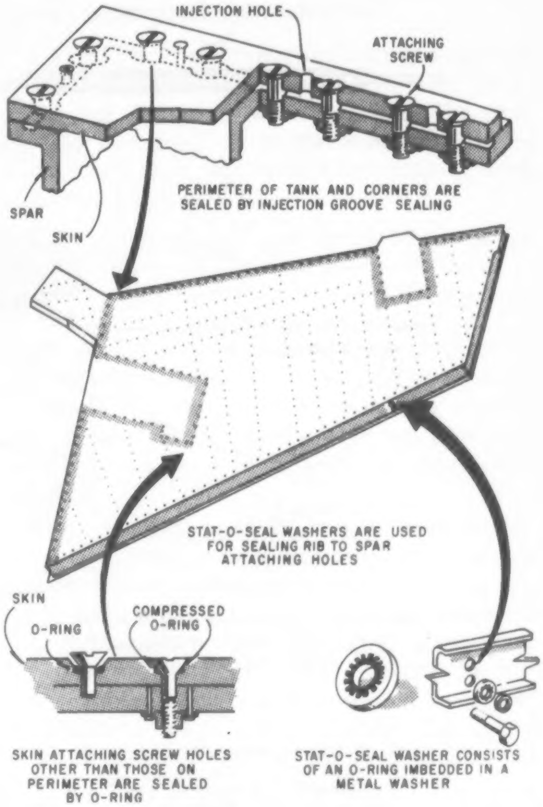
The wing mating surfaces are built to extremely close tolerances to allow for proper sealing. The sealing of these mating surfaces is attained by the use of gaskets or sealants, or a combination of both. In most cases, the perimeter of the cell is sealed by the use of a non-hardening sealant which is injected into a groove machined in one structural member along the mating surface. The attachment screws and rivets are sealed by placing O-ring seals under the heads. Protruding boltheads are sealed by special seals which consist of an O-ring embedded in a metal washer. These special seals are manufactured under various trade names such as Stat-O-Seal or Lock-O-Seal. Figure 11-5 illustrates the sealing of integral fuel cell screws and bolts.

Inspection

The inspection of integral fuel cells consists mainly of a check for external leakage around skin joints, rivets, screws, and bolts on every preflight inspection. The fuel cell fittings and connections should also be inspected for evidence of leakage. Fuel cell leaks are classified in the following categories: Slow seep, seep, heavy seep, and running leak.

SLOW SEEP.–The least severe leak classification is the slow seep. This is a very slow fuel seepage which wets a small area. Over a period of hours the wetted area may become larger. A slow seep, when wiped dry, will not reappear in a short period of time.

SEEP.–A seep is a fuel leak which reappears in less than an hour (approximately) after it has been wiped dry.


INJECTION HOLE
ATTACHING SCREW
PERIMETER OF TANK AND CORNERS ARE SEALED BY INJECTION GROOVE SEALING
SPAR
SKIN
STAT-O-SEAL WASHERS ARE USED FOR SEALING RIB TO SPAR ATTACHING HOLES
SKIN
O-RING
COMPRESSED O-RING
SKIN ATTACHING SCREW HOLES OTHER THAN THOSE ON PERIMETER ARE SEALED BY O-RING
STAT-O-SEAL WASHER CONSISTS OF AN O-RING IMBEDDED IN A METAL WASHER

AM.570

Figure 11-5.–Sealing integral cell screws and bolts.

HEAVY SEEP.–A heavy seep is a fuel leak which reappears immediately after it has been wiped dry.

RUNNING LEAK.–A running leak is a fuel leak which flows steadily.

Most aircraft Structural Repair Manuals do not classify a slow seep or seep in an open area (the surfaces of the aircraft exposed to the airstream) as a flight hazard. A slow seep or seep in an open area need not be repaired before flight if structural integrity exists and there is no danger of an increase in leak intensity during flight. Slow seeps and seeps considered acceptable for flight should be frequently inspected to insure the leak intensity does not increase prior to flight.

Heavy seeps and running leaks are classified as flight hazards, regardless of their location in the aircraft. Any leak classified as a flight hazard must be corrected before flight.

Maintenance

Leaks are the most common trouble encountered with integral fuel cells. Slight leaks may sometimes be repaired simply by retorquing (tightening) the bolts or screws on either side of the leak. On others it is often necessary to reseal the injection groove around the perimeter of the wing, and replace the O-rings and Stat-O-Seal washers. Both of these procedures are described in the following paragraphs.

RETORQUING.–Always retorque to stop a fuel stain or seepage before attempting to reseal. The first step in stopping a leak is to retorque the bolts or screws for 6 inches on each side of the leaking area according to the torque values given in the applicable Maintenance Instructions Manual for the different size bolts and screws being used. Standard bolts are used primarily in attaching wing skin and should be torqued from the nut side according to standard torque tables.

REPLACING SEALS.–If, after retorquing, the leak still persists around a bolt using a Stat-O-Seal, replace the seal with a new one. Be sure to install a washer between the bolthead and the Stat-O-Seal or leakage will still occur. Also, be sure to torque the bolts according to the torque values listed in the applicable Maintenance Instructions Manual.

If the leak is around an O-ring seal, replace the O-ring as follows: Loosen the bolt or screw with a steady pressure. Back out the bolt only as far as necessary to remove the O-ring over the head of the bolt or screw, using petrolatum (Vaseline) if desired. Install a new O-ring and tighten the bolt to the required torque.

The bolt should not be completely removed because of the possibility of cross threading during reinstallation. Cross threading could result in the loss of a structural fastener by stripped threads on the nut plate or by the threads locking and twisting.

REINJECTING SEALANT.–If the leak is at the perimeter of the tank, reinject the sealant as follows: Using integral fuel tank groove injector compound, fill the groove sealant injector gun.

NOTE: Be sure that the gun is filled in such a manner that no air is trapped in the sealant. Provide air pressure at the inlet of the gun in accordance with the gun manufacturer's instructions.

CAUTION: The ability of the sealant compound to seal depends upon its adhesion to metal. Oils and greases are adhesion breakers and MUST be completely removed from all sealing areas, injection tools, and mechanics' hands when operating or servicing the injection gun. In this group of contaminants are included hair oils, body oils, and protective hand creams.

Remove the screws from the injection holes of the area to be sealed and place the sealant gun nozzle tip into the countersink of the injection hole, as shown in Figure 11-6. Special fittings may be attached between the gun tip and the barrel for use in areas of limited accessibility.

Hold the gun firmly in position and depress the trigger until a plug of sealing compound at least 1 inch in length flows out of the next adjacent injection screw hole.

CAUTION: It is essential that the groove between injection holes be filled by injection from one direction only. If the sealant is forced into these areas from two directions, it is possible that air bubbles will be trapped in the groove. When injection has been inadvertently made from two directions, sealant should be injected from one side until a plug of sealant 5 inches long has been extruded.

NOTE: The trigger must be released approximately every 30 seconds to allow the gun piston to return before another cycle can begin.

Replace the screw in the hole which has just been injected. Proceed in the same manner on the next adjacent hole (the one from which sealant has protruded), until the area to be resealed is completed. After all injection hole screws have been installed, remove excess sealing compound from the wing by scraping with a wood or plastic blade. The area may be cleaned with solvent.

CAUTION: Do not use toluene for cleaning on any surface with a corrosion-resistant or fuel-resistant coating.

If the sealant is exceptionally slow to inject, the tank may be heated to 110° F. Heating can be accomplished by the use of electric blankets.

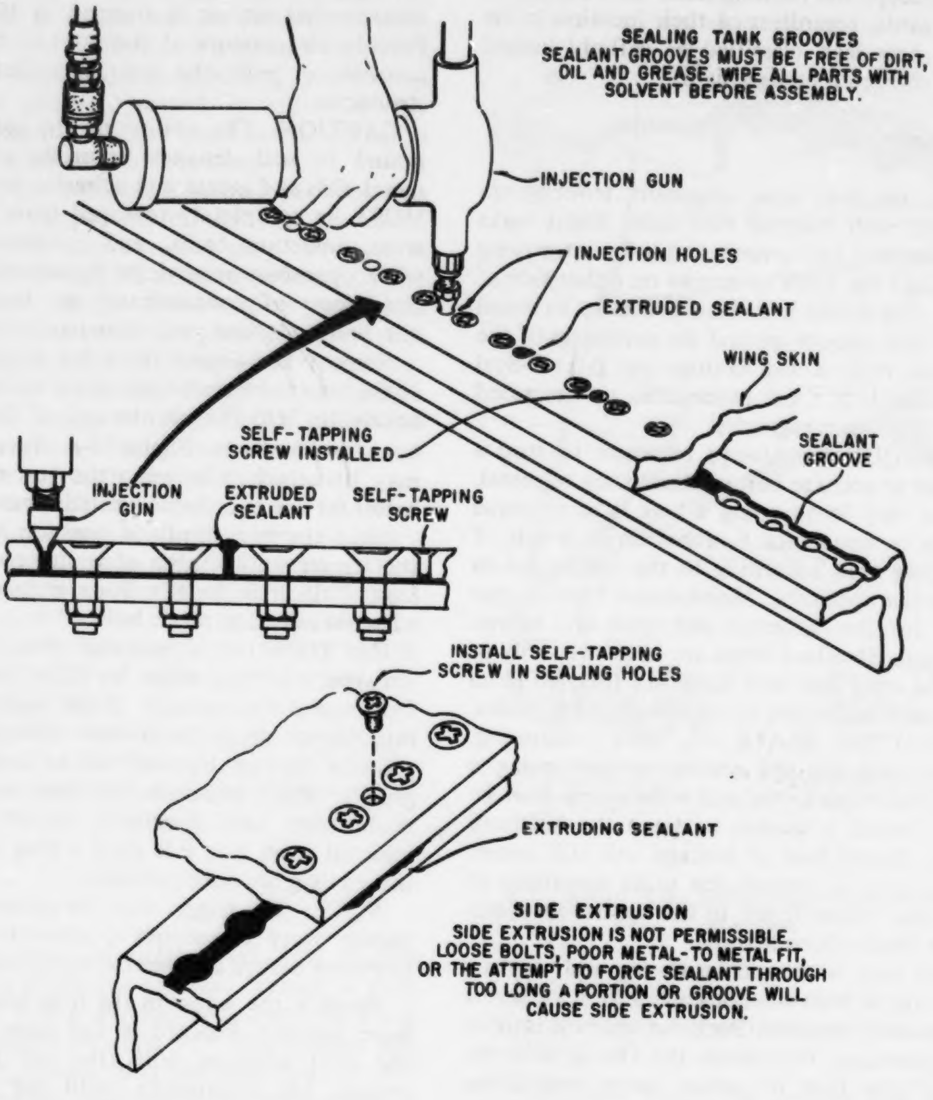

SEALING TANK GROOVES
SEALANT GROOVES MUST BE FREE OF DIRT, OIL AND GREASE. WIPE ALL PARTS WITH SOLVENT BEFORE ASSEMBLY.
INJECTION GUN
INJECTION HOLES
EXTRUDED SEALANT
WING SKIN
SEALANT GROOVE
SELF-TAPPING SCREW INSTALLED
INJECTION GUN
EXTRUDED SEALANT
SELF-TAPPING SCREW
INSTALL SELF-TAPPING SCREW IN SEALING HOLES
EXTRUDING SEALANT
SIDE EXTRUSION
SIDE EXTRUSION IS NOT PERMISSIBLE. LOOSE BOLTS, POOR METAL-TO METAL FIT, OR THE ATTEMPT TO FORCE SEALANT THROUGH TOO LONG A PORTION OR GROOVE WILL CAUSE SIDE EXTRUSION.
AM.572

Figure 11-6.—Injection of sealing compound.

CAUTION: Do not heat the tank in excess of 110° F for sealing of the injection groove.

The proper temperatures for ideal sealing conditions are 79° to 84° F. If the tank is exposed to temperatures below 50° F, the tank must be heated in excess of 70° before sealing is attempted. This may be accomplished in a heated hangar or by using portable heating units or electric blankets.

NOTE: If the sealing compound does not appear after approximately 4 to 5 minutes it may be assumed that the compound is too cold, the groove is plugged, or the surface gap is excessive. In this case, the injection should be discontinued until the discrepancy is remedied.

Testing

When an integral fuel cell has been repaired, it must be pressure checked before it is filled with fuel. Since the pressure testing procedure will vary with different type aircraft, always consult the Structural Repair Manual for the aircraft concerned for the proper procedure. Some of the equipment used for pressure testing a system are listed below:

1. A source of nitrogen and a means of regulating the nitrogen pressure.

NOTE: The use of nitrogen for pressure testing the fuel system is recommended since nitrogen is an inert gas and therefore presents no explosive hazard when introduced into a fuel cell containing fuel vapors. A source of dry air could be used but, since this would increase the ratio of oxygen to fuel vapors in the cell, the possibility of an explosion would be increased. Therefore, dry air is not recommended.

2. Suitable hoses and fittings to connect testing euqipment to fuel system.
3. A 0 to 5 psi pressure gage installed downstream of the nitrogen supply.
4. Miscellaneous plugs and caps required for blocking off various lines and fittings.

DEICER BOOTS

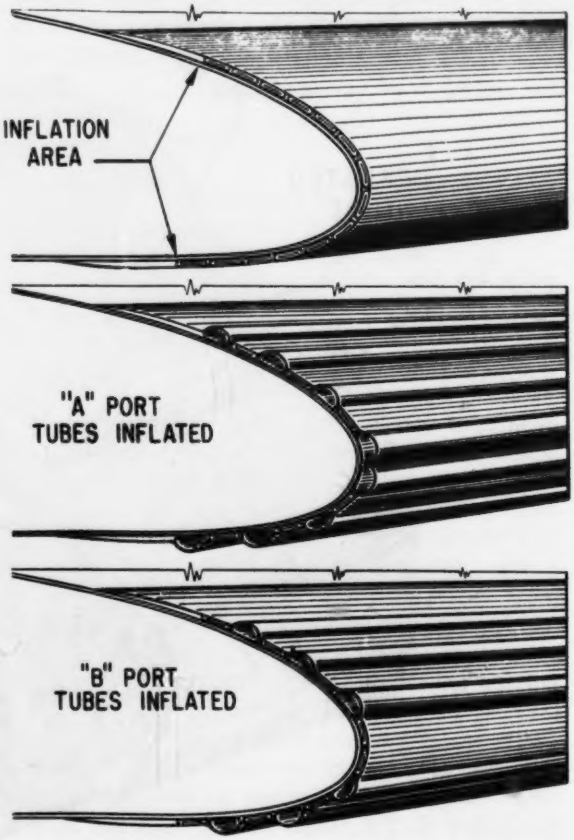
The formation of ice on the leading edges of aircraft surfaces presents a serious problem for aircraft operating at low temperatures. Besides adding unnecessary weight to the aircraft, ice formations change the airfoil characteristics of a surface, thus creating serious flight hazards. One method of removing ice formations is by the use of deicer boots. Deicer boots are used in removing ice formations from the leading edges of wings and tail surfaces, and in some instances, antenna masts.

The deicer system operates by means of compressed air, supplied by engine-driven pumps or by compressor bleed air from jet engines. Each deicer boot contains a number of inflatable cells. These cells are inflated and deflated alternately, causing a wave-like motion which cracks the ice that has formed. (See Fig. 11-7.) Once the ice has been cracked, the airstream peels it back and carries it away.

DEICER BOOT CONSTRUCTION

Deicer boots are made of soft, pliable rubber or rubberized fabric and contain tubular air cells. These deicer boots are attached to the wing surface with cement or fairing strips and screws or a combination of both.

Deicer boots which are secured to the surface with fairing strips and screws or a combination of fairing strips, screws, and cement have a bead and bead wire on each lengthwise edge. On this type installation screws pass through a fairing



AM.573
Figure 11-7.—Deicer boot operation.

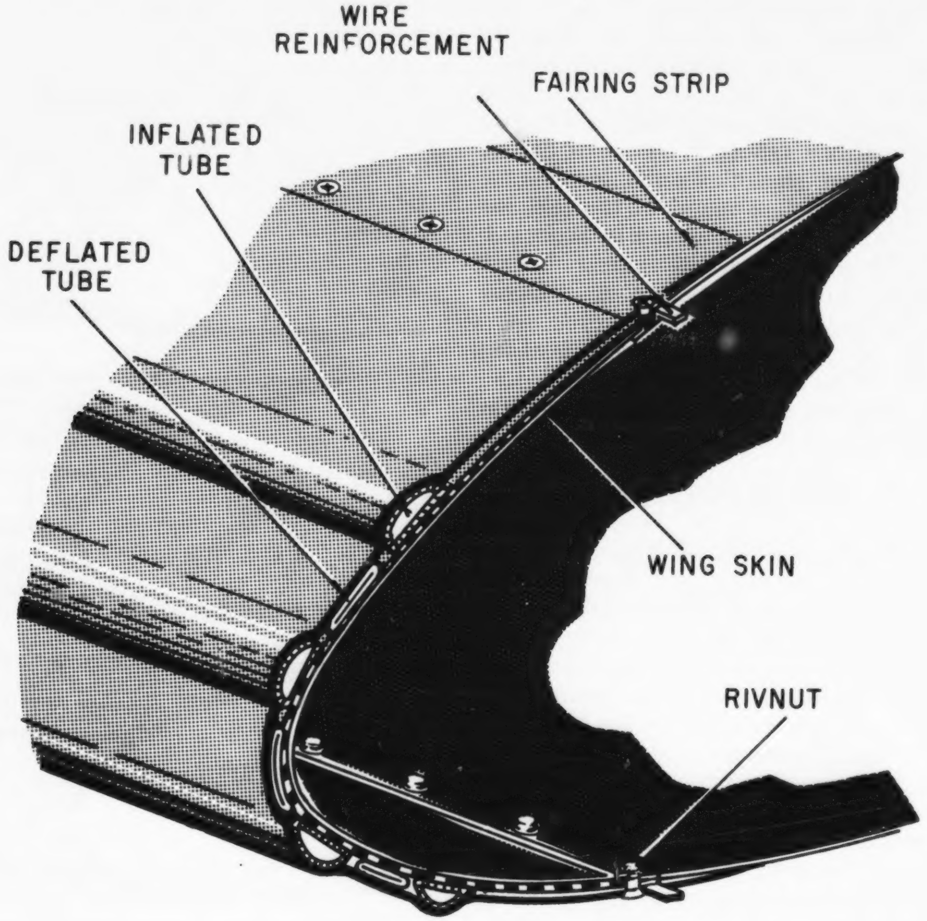
strip and the deicer boot just ahead of the bead wire and fit into Rivnuts located permanently in the skin of the aircraft.

The newest type deicer boot is completely bonded to the surface with cement. The trailing edges of this type boot are tapered to provide a smooth airfoil. By eliminating the fairing strips and screws this type installation cuts down on the weight of the deicer system.

The deicer boot air cells are connected to system pressure and vacuum lines from the pump by nonkinking flexible hose. Figure 11-8 shows a cross section of a typical deicer boot installation.

INSPECTION AND MAINTENANCE

Maintenance of the deicing system is normally performed by personnel of the AME, AMS, and AE ratings. The AME is generally responsible for the operation of deicing systems. Personnel of the AMS rating are usually concerned with the replacement and upkeep of the deicer boots, while personnel of the AE rating are concerned



AM.575

Figure 11-8.—Deicer boot cross section.

with the removal and replacement of electrical units within the deicing system.

General Maintenance

Deicer boots, like other items made of rubber, are affected by exposure and extended use, both of which cause deterioration. Located as they are on the leading edges of the wings and tail surfaces, deicer boots are subjected to abrasion by sand and sleet. Grease, oil, and other foreign materials which cause deterioration are also blown onto the surface of the boots by the airstream. It is, therefore, good practice to clean all exposed surfaces periodically, using a neutral soap and water solution. A recommended solvent may be used if necessary; however, care should be taken not to scrub the surface as this will remove the special graphite coating which is provided to eliminate static electricity.

Carelessness on the part of maintenance personnel also shortens the service life of deicer boots, often making replacement necessary. The most common causes of damage are dragging of fuel hoses over the boots and scuffing them with work platforms. Leading petty officers should caution their men against such work habits. Common sense dictates a "no step" policy for the installed deicer boot.

When the use of excessive cleaning solvent has removed the electrical conductive coating, the boots should be resurfaced. This is done by applying a conductive cement (prenitegraphite) to the surface.

In resurfacing, first clean the outer surface of the boot with a suitable solvent, as recommended in the applicable Maintenance Instructions Manual. Next, mask off the fairing strip so as to shield the wing surface during the spraying operation.

Spray a smooth coat of conductive cement on the deicer boot surface. Where areas are badly worn, additional coats may be necessary. After application, the cement coating must be allowed to dry in a clean, warm place for a minimum of 24 hours.

Inspection

During ground checks the operation of the deicers should be observed. Inflation and deflation of the cells should be rapid and complete. The proper sequence of inflation should be checked. The pressure and suction gages should show the correct amount of pressure and vacuum, respectively.

After the last flight of the day, the boots themselves should be inspected for cleanliness and general condition.

Periodically, the boots should be thoroughly checked for such discrepancies as checking, cracking, tears, holes, scuffs, and loose fairing strips and clamps. If any of these conditions are detected, the boot must be repaired or replaced, as necessary.

In some cases excessively long use or absorption of oil may cause an increase in the width of a boot. Since all boots are designed to operate under a predetermined amount of tension, this condition calls for replacement when the increase in width amounts to 2 percent or more.

Deicer Boot Repair

If the damage is extensive, the boot should be removed and repaired by vulcanizing. This is considered as a permanent type repair.

The method most commonly used to repair deicer boots is the cold patch method. The cold patch is a temporary or emergency method of repair but can be considered permanent if performed in a neat, workmanlike manner. Therefore, it is generally unnecessary to remove the deicer boots during their service life unless the damage is extensive.

Repair kits are available for making cold patch repairs. They consist of assorted sizes of specially prepared rubberized patches and a sheet of fabric-reinforced repair material from which patches can be cut.

When making cold patch repairs on cuts or tears in the tube area at right angles, or parallel to the tubes, use reinforced neoprene patches cut from the fabric repair material in the repair kit. For cuts or tears not in the tube area, use molded patches or patches cut from the sheet repair material in the repair kit. If this sheet repair material is used, the edges should be beveled by cutting at an angle. Since deicer boot patches made from the fabric reinforced material stretch in only one direction, they must be applied in the direction of stretch of the boot. All repairs to deicer boots should be made in accordance with the instructions found in the applicable Maintenance Instructions Manual. General information concerning the care and maintenance, installation, inspection, and repair of deicer boots may be found in NavAir 03-35B-504, Deicer Instruction Manual.

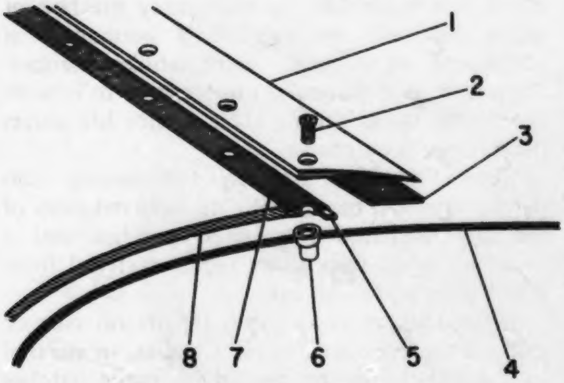
Removal and Installation

The procedure for removal and installation of deicer boots varies to some extent with different types of aircraft. Detailed instructions are therefore included in the applicable Maintenance Instructions Manual and should always be followed. Figure 11-9 illustrates one method of attachment of the boots to the aircraft structure, and Figure 11-10 illustrates the installation tools used.

Some of the general precautions that should be observed in the removal and installation of deicer boots are listed below.

Always cap or plug all disconnected hose lines when the deicer boots are removed from the aircraft.

When any portion of a deicer boot must be removed, loosen the cement bond by wiping with a clean cloth or brush dipped in a recommended solvent and pulling up gently on the deicer boot.



AM.576

1. Fairing.
2. Attachment screw.
3. Industrial tape, 1/2 inch.
4. Wing skin.
5. Beadwire.
6. Rivnut.
7. Bead.
8. Deicer boot.

Figure 11-9.—Deicer boot attachment.

Prior to installing deicer boots wash all metal surfaces with a clean cloth dampened with MEK or toluene.

SEALANT REPAIR

Specific areas of all naval aircraft are sealed to withstand pressurization by air, prevent leakage of fuel, prevent passage of fumes, and the prevention of corrosion by sealing against the weather. When sealant materials are applied to aircraft structures they are considered to be a permanent part of the structure. The study of airframe repair necessarily includes a study of materials and techniques applicable to sealants and no structural repairs may be considered complete until the air-or liquid-tight integrity of the structure has been restored. Sealant repair requires a thorough knowledge of the proper procedure, technique and tools used for application, and careful planning of the sequence and time element involved.

All sealant repair should be done in accordance with the instructions found in the aircraft Structural Repair Manual. The Structural Repair Manual gives test procedures for finding leaks and specifies the materials to be used for each type of repair.

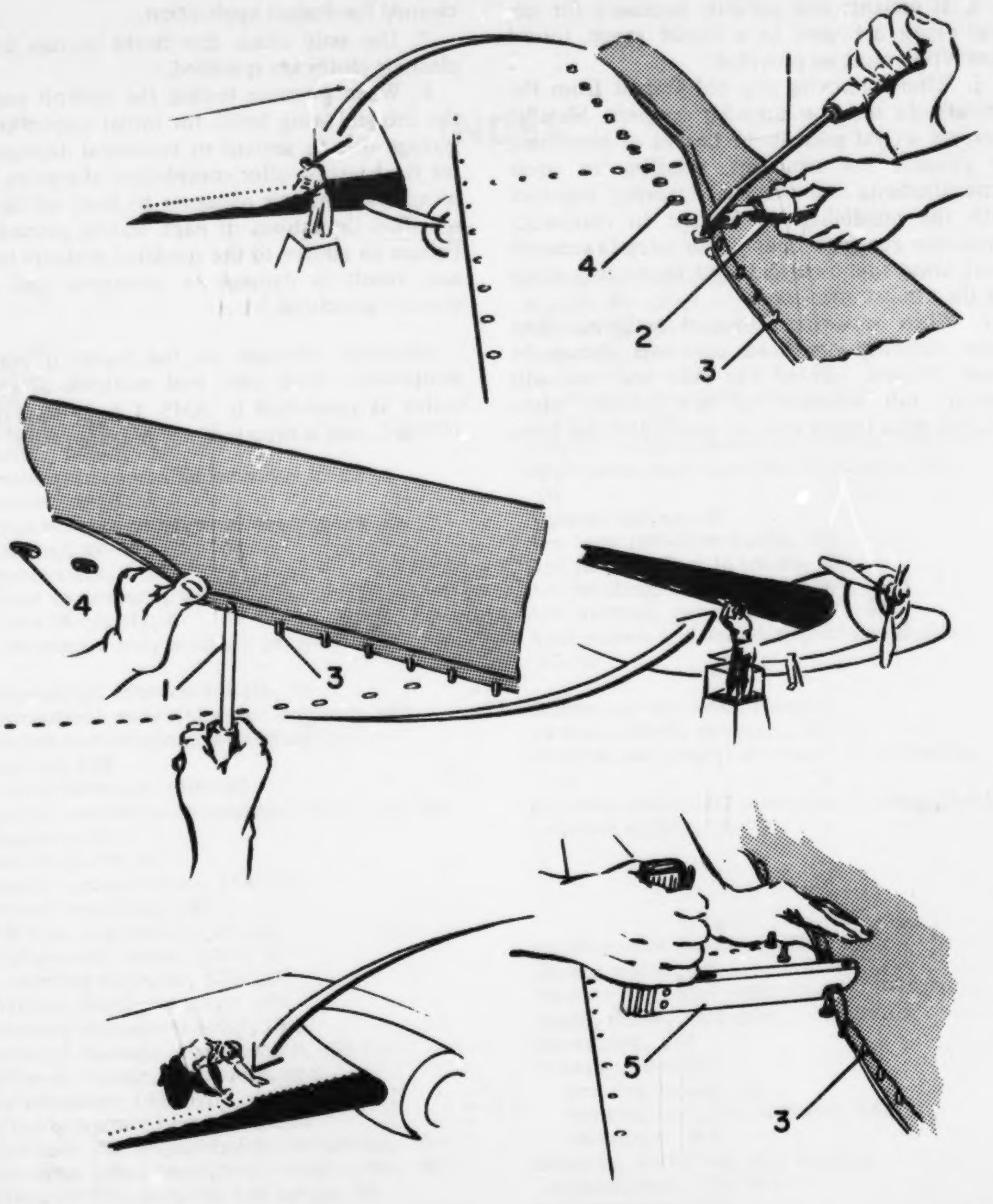
All organic compound sealants used in sealant repair must be carefully prepared in accordance with the instructions prescribed by the sealant manufacturer.

When effecting sealant repairs, the following precautions should be adhered to:

1. Avoid skin contact with organic sealants and the cleaning compounds used in sealing preparations. Rubber gloves and goggles should be worn while working with solutions. If a solution accidentally contacts the skin or eyes, it should be washed off immediately with large quantities of clear water. Report to sick bay in all cases when the eyes are affected or if the skin is burned.

2. When effecting sealant repairs of any kind, the aircraft must be grounded, electrical equipment rendered inoperative, and any external power source disconnected.

3. Use explosion-proof lights and spark-proof tools.



1. **Positioning tool.**
2. **Pushing tool.**
3. **Installation peg.**
4. **Rivnut.**
5. **Tensioning tool.**

Figure 11-10—Deicer boot attachment tools.

4. If sealants and solvents necessary for sealant repair are used in a closed space, forced ventilation must be provided.

5. When removing the old sealant from the aircraft do not use metallic scrapers. Metallic scrapers would present the hazard of scratching or gouging the structure, resulting in stress concentrations and eventual cracking, together with the possibility of damage to corrosion-protective coatings. Phenolic or micarta scrapers must always be used and kept reasonably sharp for the utmost efficiency.

6. When repairing damaged sealants, clean outer clothing and head coverings should be worn. Natural oils of the skin and hair will prevent full adhesion of new sealant when brushed even lightly over an area which has been cleaned for sealant application.

7. Use only clean, dry cloths or rags where cleaning cloths are specified.

8. When pressure testing the cockpit area or the integral wing tanks for initial inspection of leakage due to sealant or structural damage, or for final testing after completion of repairs, it is mandatory that air pressures be kept within the specified limitations of each testing procedure. Failure to adhere to the specified pressure limits may result in damage or overstress and subsequent structural failure.

Adequate coverage on the types of sealing compounds, their uses, and methods of application is contained in AMS 3 & 2, NavEdTra 10308-C, and is therefore not repeated here.

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NONRESIDENT CAREER COURSE

AVIATION STRUCTURAL MECHANIC S 1&C

NAVEDTRA 10311-C2

This self-study course is only one part of the total Navy training program. By its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and YOUR desire to succeed are also necessary to round out a fully meaningful training program.

Your Nonresident Career Course (NRCC) contains a set of assignments and perforated answer sheets. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the Rate Training Manual (RTM) or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

You should read the RTM before taking the NRCC. Study the RTM pages given at the beginning of each assignment before trying to answer the questions. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. You should read the learning objectives preceding each set of questions. The learning objectives and questions are based on the subject matter of the RTM. The learning objectives tell you what you should be able to do after studying the RTM. Answering the questions should help you accomplish the objectives.

At this point, you should be ready to answer the questions in the assignment. Read each question carefully. Select the BEST ANSWER for each question, consulting your RTM when necessary. Be sure to select the BEST ANSWER from the subject matter in the RTM. You may discuss difficult points in the course with others. However, the answer you select must be your own. Remove a perforated answer sheet from the back of the NRCC, write in the proper assignment number, and enter your answer for each question.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning a 3.2 for each assignment. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed answer sheet to the officer designated to grade it. The graded answer sheet will not be returned to you.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make an entry in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your completed answer sheets to the Naval Education and Training Program Development Center where they will be graded and the score recorded. Make sure all blanks at the top of the answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. The graded answer sheets will not be returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the RTM and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the RTM and assignments are given on the course disenrollment-course completion form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068, lists by paygrade the minimum tasks you must be able to perform in your rating. These tasks are called occupational standards. Your examination for advancement is based on these occupational standards. The material used to prepare the questions for your advancement examination is listed in the *Bibliography for Advancement Examination Study*, NAVEDTRA 10052. For your convenience, the occupational standards and the bibliography for your rating are combined in a single booklet for the examinations given each year. These *Occupational Standards and Bibliography* booklets are available from your Educational Services Officer (ESO). Even though you have met the course requirement by successfully completing this NRCC, you should continue to study the RTM as you prepare for the advancement examination. Remember the RTM is one of the sources for advancement examination questions. Because the qualifications for your rating may have changed since your RTM was printed, you should refer to the latest annual edition of the rating *Occupational Standards and Bibliography* booklet.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 9 Naval Reserve retirement points which will be credited upon satisfactory completion of the entire course. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel.

COURSE OBJECTIVE

While completing this Nonresident Career Course, the student will answer items correctly that relate to the professional aspects of the Aviation Structural Mechanic S rating: airframe repair, alignment, and maintenance; heat treatment and testing of metals; nondestructive inspection of metals; oxyacetylene welding, brazing, and soldering; electric arc welding; gas shielded arc welding; and finally, nonmetallic materials.

While working on this correspondence course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval courses may include several types of questions—multiple-choice, true-false, matching, etc. The questions are not grouped by type but by subject matter. They are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Not all courses use all of the types of questions available. The student can readily identify the type of each question, and the action required, by inspection of the samples given below.

MULTIPLE-CHOICE QUESTIONS

Each question contains several alternatives, one of which provides the best answer to the question. Select the best alternative, and blacken the appropriate box on the answer sheet.

SAMPLE

s-1. Who was the first person appointed Secretary of Defense under the National Security Act of 1947?

1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	☐	■	☐	☐	- - -

TRUE-FALSE QUESTIONS

Mark each statement true or false as indicated below. If any part of the statement is false the statement is to be considered false. Make the decision, and blacken the appropriate box on the answer sheet.

SAMPLE

s-2. All naval officers are authorized to correspond officially with any systems command of the Department of the Navy without their respective commanding officer's endorsement.

1. True
2. False

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	☐	■	☐	☐	- - -

MATCHING QUESTIONS

Each set of questions consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Items in column B may be used once, more than once, or not at all. Specific instructions are given with each set of questions. Select the numbers identifying the answers and blacken the appropriate boxes on the answer sheet.

SAMPLE

In questions s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions. Some responses may be used once, more than once, or not at all.

A. OFFICER	B. DEPARTMENT
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Disbursing Officer	3. Supply Department
s-6. Communications Officer	

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	☐	■	☐	☐	- - -
s-4	■	☐	☐	☐	- - -
s-5	☐	☐	■	☐	- - -
s-6	■	☐	☐	☐	- - -

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Assignments 1 through 4 have been deleted.

Pages 2 through 28 have been deleted.

Assignment 5

Airframe Repair, Alignment, and Maintenance; Heat Treatment.

Text: Pages 102-143

Learning Objective: Relative to airframe damages, recognize common causes and results, inspection methods, and classification.

5-1. Which causes of aircraft damage can be controlled through proper supervision of maintenance personnel?

1. Collision and foreign object
2. Foreign object and stress
3. Collision and corrosion
4. Corrosion and stress

5-2. Which of the following will result from a projectile passing through an aircraft structure?

1. The metal around the damaged area will become brittle as a result of the heat created by the impact
2. Minute cracks will be created around the hole as a result of the impact
3. The hole will be largest on the side opposite that in which the projectile entered
4. All of the above will result

5-3. When no other signs of damage are present, loosened rivets in the skin of an aircraft are usually the result of

1. corrosion
2. a hard landing
3. a manufacturing defect
4. a minor collision

In items 5-4 through 5-6, select from column B the method employed for each inspection listed in column A.

A. Inspections

5-4. An internal inspection on an area that cannot be disassembled

5-5. An inspection for subsurface damage that may have occurred to the attaching points of a landing gear during a hard landing

5-6. An inspection of a discolored area adjacent to an engine air bleed tubing connection

B. Methods

1. Penetrant
2. Hardness testing
3. Borescope
4. Magnetic particle

5-7. Damage at the opposite end of a structural member that has received primary damage would be classified as secondary damage.

5-8. If while inspecting an aircraft for damage, you discover deep scratches in a small area of a wing surface, what action should you take?

1. Burnish the area
2. Cut out and repair the area
3. Subject the area to a dye penetrant inspection
4. Classify the damage as negligible and let it go

5-9. During an inspection a section of the fuselage skin is found roughened by flying sand. This damage is classified as

1. negligible
2. repairable by insertion
3. repairable by patching
4. necessitating replacement

Learning Objective: Identify types of airframe damage, and indicate procedures involved in making internal structural repairs, in fabricating parts, a in repairing stringers, spars, ribs, and bulkheads.

5-10. If airframe damage is repairable, the type of repair to be made will depend upon

1. the maintenance level that will do the job
2. the amount of time that can be used
3. the materials and tools that are available
4. all of the above

5-11. Which type of structural repair will restore the load carrying capability of the structure even though it does not satisfy interchangeability requirements or is not aerodynamically smooth?

1. External
2. Permanent
3. Temporary
4. One-time flight

5-12. Which step should you take first in making an internal structural repair?

1. Plan the repair
2. Support the adjacent structural members
3. Remove the damaged member
4. Inspect and classify the damage

5-13. When applied to aircraft structural repair, to "layout" is to interpret information and transcribe it from a blueprint, drawing, or written instruction to a piece of metal that will be made into an aircraft part.

In items 5-14 through 5-16, select from column B the instrument that is most closely identified with each statement about layout procedures given in column A.

	A. Statements	B. Instruments
5-14.	Lines at an angle or parallel to the straight edge should be made by marking off points on the metal with this instrument.	1. Scriber 2. Magnifying glass 3. Dividers
5-15.	This instrument should be used to form the intersection of two reference lines on the metal.	4. Combination square
5-16.	Precision fabrication and inspection can be aided by the use of this instrument	

- Refer to table 4-1 in your textbook in answering 5-17 and 5-18.

5-17. What is the minimum bend radius that can be used on a piece of 7075-0, 0.050-gage aluminum sheet stock?

1. 1/32 inch
2. 3/32 inch
3. 5/16 inch
4. 1/4 inch

5-18. Which 0.050-gage material requires the largest minimum bending radius?

1. 2024-0
2. 6061-0
3. 7075-T6
4. 7075-0

5-19. Refer to figure 4-3 in your textbook. How long should the reinforcement splice be on a stringer with a 3-inch filler splice if the width of the stringer is 2 inches?

1. 7 inches
2. 11 inches
3. 16 inches
4. 19 inches

5-20. If airframe work center personnel are granted permission to repair a damaged spar, they must do the work in accordance with the instructions contained in the

1. Repair Manual of the applicable spar
2. Manufacturer's Structural Handbook
3. Structural Repair Manual for the applicable aircraft
4. General Structural Repair Manual

5-21. What is an advantage of the use of a former rib rather than a truss or reinforced rib?

1. It is lighter
2. It is stronger
3. It does not require lightening holes
4. It is more adaptable for use in larger aircraft

5-22. The beads on a former rib serve what purpose?

1. They lighten the rib
2. They reinforce the flange
3. They keep the flange rigid
4. They stiffen the web

5-23. If you discover a crack in the web of a bulkhead, you should use the same type of repair you would use on

1. fully stressed skin
2. lightening hole repairs
3. stringers and longerons
4. buckled webs

Learning Objective: Indicate procedures related to removing and installing wings and stabilizers, including the determination of torque values.

5-24. Which of the following precautions should be taken when removing a wing?

1. Instructions in the applicable MIM should be followed when disconnecting tubing, electrical connectors, control cables, and bonding wires
2. Operation of all disconnected mechanisms should be checked and the necessary rigging adjustments made in accordance with the applicable MIM
3. The wing should be properly supported removed
4. Both 1 and 3 above should be done

5-25. If, during the removal of an aircraft wing, the structural bolts cannot be removed by hand, what should you use in addition to a mallet to remove them?

1. A brass drift pin
2. A heavy bucking bar
3. Another bolt of the same size
4. An alignment pin

5-26. After removing a damaged wing and before installing a new wing you should inspect all fittings, connections, and unremoved structural members for damage which may have resulted from the transmission of the shock or load which caused the primary damage.

5-27. What is a purpose of applying a designated amount of torque to a fastener?

1. To decrease torsion and tension
2. To increase torsion and tension
3. To increase torsion and decrease tension
4. To increase tension and decrease torsion

5-28. Refer to table 4-3 in your textbook. What is the maximum allowable tightening torque limit for a 3/8-16 cadmium-plated steel shear nut of the coarse thread series if the bolt has a tensile strength of 54,000 psi?

1. 170 inch-pounds
2. 240 inch-pounds
3. 275 inch-pounds
4. 390 inch-pounds

5-29. Which of the following rules will apply to torquing nuts and bolts?

1. If possible, torque the nut rather than the bolt
2. Do not exceed maximum torque by more than 10 percent
3. If the torque is applied to the bolt, approach the high side of the indicated torque range
4. Both 1 and 3 above will apply

5-30. What will be the toque indicated on a 12-inch torque wrench employing a 6-inch drive-end extension used to tighten a 9/16-18 shear nut to 500 inch-pounds?

1. 280 inch-pounds
2. 333 inch-pounds
3. 480 inch-pounds
4. 500 inch-pounds

Learning Objective: Indicate methods and procedures for leveling and aligning aircraft.

5-31. An alignment check of the airframe should be made if an aircraft has

1. made a hard landing
2. encountered excessive G's in flight
3. been subjected to extensive damage
4. experienced any of the above conditions

5-32. Which method may be used to level an aircraft prior to checking its alignment?

1. Transit leveling
2. Spirit leveling
3. Plumb bob and datum plate leveling
4. Any of the above, if specified by the aircraft's manufacturer

5-33. If the leveling lugs of an aircraft are found to be damaged and are repaired, the accuracy of their alignment can be determined with a

1. surveyor's transit
2. plumb bob
3. spirit level and surveyor's transit
4. plumb bob and a datum plate

5-34. If you make an alignment check of an aircraft you must first level it and then measure the distances between certain points which, due to their locations and static positions, best reflect any misalignment.

5-35. The first step in checking horizontal alignment after an aircraft is leveled is to

1. use a leveled transit to measure the distances between checkpoints on the aircraft
2. suspend plumb bobs of equal length from checkpoints on the point of each plumb bob with a leveled transit
3. suspend plumb bobs from checkpoints on the aircraft and measure the distance between the tips of the plumb bobs
4. suspend plumb bobs from checkpoints on the aircraft and compare with the height of the lowest point on the aircraft

---

Learning Objective: Relative to flight control maintenance, identify typical malfunctions and related corrective techniques and inspections.

5-36. As an AMS1 or AMSC, one of your major responsibilities is to supervise maintenance of flight control systems and to stress to your work center personnel the importance of thoroughly inspecting each system on the aircraft.

5-37. Relative to control system inspections, the term "proper control surface response" means that all control surfaces and their related linkages must move smoothly and freely through their entire operating ranges.

5-38. What is a function of a schematic diagram?

1. To identify each of the components within an assembly
2. To locate components in relation to each other within a system
3. To locate components in relation to each other within a system
4. To show the location of individual components within an aircraft

---

Refer to table 4-4 in your textbook. In items 5-39 through 5-41, select from column B the probable cause of each flight control system malfunction listed in column A.

A. Malfunctions	B. Probable Causes
5-39. Controls operate jerkily during flight	1. Worn bearings in the pully or bellcrank
5-40. Control surfaces will not attain full travel	2. Cable tension too low
5-41. Controls catch or bind	3. Rig pin installed
	4. Undersize or worn hinge bolt

5-42. Refer to table 4-5 in your textbook. The remedy for "No lateral trim" is a reference to the applicable

1. NATOPS Flight Manual
2. Structural Repair Manual
3. Maintenance Instructions Manual
4. Illustrated Parts Breakdown Manual

5-43. From the following steps, select the correct sequence you should take when rigging a flight control system:

A. Neutralize each bellcrank in the system
B. Check the control surface for neutral position with the appropriate rigging fixture
C. Secure the cockpit control device in a neutral position
D. Check control surface travel from the neutral position
E. Establish correct cable tension
F. Set the adjustable stops to prevent overtravel

1. A, C, D, B, F, E
2. A, D, C, B, F, E
3. C, A, B, E, D, F
4. C, B, A, D, E, F

5-44. What should you do if, after installing a new actuator in a power boost flight control system, the control surface will not attain full travel even though cable tension is correct and the proper clearance is maintained between the stops and bellcrank?

1. Readjust the mechanical stops
2. Cycle the control surface through full travel at least 15 times
3. Adjust actuator piston rod end until control surface travel falls within limits
4. Replace all hinge bolt and reset cable tension

Learning Objective: Recognize reasons and procedures for tracking the main rotor blades of an SH-3A helicopter.

5-45. Tracking the blades must be performed whenever

1. the helicopter is rerigged
2. the main gearbox is replaced
3. the rotor head assembly and rotor blades are replaced
4. any of the above occurs

5-46. The blades must be tracked to insure that they all rotate within the same horizontal plane.

5-47. You are not permitted to interchange or replace blades individually because each one is balanced statically and dynamically at the time of manufacture.

5-48. When tracking blades after installation, you must set each adjustable pitch control rod to the pretrack number stenciled on the underside of the blade. If this number is PLUS, and the adjustable pitch control decal indicates that it is set at 0, you must loosen the locknut and

1. lengthen the rod by rotating the tang clockwise
2. lengthen the rod by rotating the tang counterclockwise
3. shorten the rod by rotating the tang clockwise
4. shorten the rod by rotating the tang counterclockwise

Learning Objective: Recognize conditions and procedures for hoisting and weighing aircraft.

5-49. Because the pitching and rolling of the ship will cause an aircraft to swing when suspended from a hoist, all maintenance work requiring the raising of an aircraft while aboard a carrier should be done with the aircraft on jacks.

5-50. Inasmuch as different types of aircraft have different centers of gravity, the points for attaching hoisting slings vary and each aircraft has a specially designed sling which is furnished as part of its ground-handling equipment.

5-51. When supervising the hoisting of an aircraft, you must be very careful to insure

1. that all safety devices are installed
2. that the correct hoisting device is used
3. that handling personnel do not stand beneath it while it is suspended
4. all of the above

5-52. Although the applicable MIM lists the specific instructions for hoisting a particular aircraft, there are also general precautions that apply.

5-53. An aircraft must be weighted when

1. required by pertinent directives
2. major repairs or modifications are made
3. unsatisfactory flight conditions are encountered
4. any of the above conditions exists

5-54. An aircraft must be weighed in a ready-for-flight condition.

Learning Objective: Recognize basic principles of heat treatment.

5-55. All of the heat treating processes are similar in that they involve heating and cooling of metals, but they differ in

1. heating temperatures
2. cooling rates
3. hardness and strength of the final product
4. all of the above

5-56. Which statement relative to the principles of heat treatment is true?

1. Three processes that may be used to caseharden steel are cyaniding, carburizing, and normalizing
2. Normalizing is the recommended treatment for relieving internal stresses in most alloys
3. In order for a metal to be hardened by heat treatment, changes must occur in its structure when it is heated
4. The term "solid solution" is more applicable to pure metal than to an alloy

5-57. Identification of the individual elements of an alloy by microscopic examination is the means of determining whether the alloy is in the form of a solid solution or mechanical mixture.

5-58. What can be the result of cooling an alloy which consists of a combination of solid solution and mechanical mixture at normal temperature and changes to a solid solution when heated?

1. It can return to its original structure
2. It can remain in a solid solution
3. It can form a complex solution
4. Any of the above can be the result

5-59. What will determine the hardness of steel at ordinary temperatures?

1. The size of the particles of iron carbide in the mixture
2. The number of particles of iron carbide in the mixture
3. The distribution of the particles of iron carbide throughout the mixture
4. All of the above

5-60. At elevated temperatures the particles of iron carbide in steel will dissolve in the mixture and form

1. ferrite
2. cementite
3. pearlite
4. austenite

Assignment 6

Heat Treatment and Testing of Metals

Text: 143-165

Learning Objective: Recognize principles, practices, and materials applicable to heat treating, hardening, tempering, annealing, normalizing, and casehardening ferrous metals.

6-1. In order to successfully heat treat ferrous metals, you must be able to control their rates of heating and cooling. This control involves the use of

1. uniform heating furnaces
2. proper temperature controls
3. suitable quenching media
4. all of the above

6-2. Relative to heat treatment of a piece of steel, which of the following is most closely associated with the soaking operations?

1. Upper critical point
2. Transformation
3. Internal change
4. Final form

6-3. Which type of quenching medium is generally used for cooling alloy steels?

1. Oil
2. Water
3. Water or oil
4. Water or brine

6-4. During the hardening process, gray iron is produced when

1. wrought iron is cooled slowly
2. pure iron is cooled slowly
3. cast iron is cooled slowly
4. cast iron is cooled rapidly

6-5. If a piece of 0.90 percent carbon steel that is in an austenitic condition is cooled to 1,000°F in 1 second, its wearability is increased due to the formation of hard

1. austenite
2. cementite
3. martensite
4. pearlite

6-6. Which of the following statements relative to hardening steel is true? Hardening increases the steel's

1. hardness and strength but increases is ductility
2. hardness and ductility but decreases its strength
3. hardness but decreases its strength and ductility
4. hardness and strength but decreases its ductility

6-7. Why is steel tempered after being hardened?

1. To increase its hardness and ductility
2. To relieve its internal stresses and reduce its brittleness
3. To decrease its ductility and brittleness
4. To increase its strength and decrease its internal stresses

6-8. The length of time that a piece of steel should be kept at the tempering temperature depends on the

1. type of steel
2. thickness of the piece
3. desired tensile strength
4. quenching medium used in hardening

6-9. Which of the following is least descriptive of the annealing process and of the steel after it has been annealed?

1. Furnace cooling --fine grain
2. Rapid cooling--high strength
3. Slow cooling--low strength
4. Slow cooling--no internal stresses

6-10. One difference between annealing and normalizing is that normalizing usually requires

1. higher temperatures and slower cooling
2. higher temperatures and faster cooling
3. lower temperatures and faster cooling
4. lower temperatures and slower cooling

6-11. Which type of steel is best suited for casehardening?

1. Low-carbon, low-alloy
2. High-carbon, high-alloy
3. Low-carbon, high-alloy
4. High-carbon, low-alloy

6-12. The gas carburizing and pack carburizing processes are similar since

1. both produce a steel that is characterized by a tough case and a hard core
2. both produce casehardened steel through the combining of carbon monoxide gas with gamma iron
3. both utilize a molten salt bath
4. either method may be used with equal success if the steel that is being carburized has a high carbon content

6-13. Flamehardening differs from the other casehardening methods in that the process is applied only to a thin surface layer or localized area of the metal being hardened.

Learning Objective: Recognize principles, practices, and difficulties associated with heat treating, hardening, and annealing aluminum alloys, including designations.

6-14. Relative to the heat treatment of aluminum alloys, the expression heat treatment may be used interchangeably with the expression

1. solution heat treatment
2. precipitation heat treatment
3. room-temperature hardening
4. soaking

6-15. The process by which aluminum alloy is allowed to harden at room temperature is known as

1. natural aging
2. artificial aging
3. solution heat treating
4. precipitation heat treating

6-16. Assume that you are heat treating a heavy aluminum forging 10 inches thick. Approximately how long should it be heat soaked?

1. 10 minutes
2. 5 hours
3. 10 hours
4. 12 hours

6-17. Whether a part will be quenched by cold water, hot water, or high velocity water spray depends on

1. the part itself
2. the type of alloy
3. the properties desired
4. all of the above

6-18. When heat treating a small aluminum forging, a cold water quench should be used to produce

1. maximum hardness
2. maximum corrosion resistance
3. minimum distortion
4. minimum diffusion

6-19. Hot or boiling water is normally used for quenching

1. tubing
2. extrusions
3. clad sheet
4. large forgings

6-20. If you are solution heat-treating 2024 aluminum alloy sheet material, you should place it in the quenching tank within 10 seconds after you remove it from the furnace.

6-21. Which of the following types of aluminum cannot be heat treated repeatedly without harmful effects?

1. 2024-W
2. 6061-T9
3. 7075-T6
4. 2024-T3 (Clad)

6-22. Which of the following defects in heat-treated aluminum could be caused by too short a soaking period?

1. Cracks
2. Low tensile and yield strength
3. Low intergranular corrosion resistance
4. Excessive diffusion

6-23. If any difficulties arise when solution heat treating aluminum alloy, the first thing that you should check is the

1. temperature controls
2. time the alloy is allow to soak
3. type and strength of the quenching medium
4. transfer time from the furnace to the quenching tank

6-24. The longer aluminum alloy is allowed to artificially age by precipitation after quenching from a solution heat-treating temperature, the stronger it will become.

6-25. As compared with an aluminum alloy that has not been subjected to precipitation hardening, one that has been subjected to it will be

1. less ductile and weaker
2. weaker, less ductile, but harder
3. harder, stronger, and more ductile
4. harder and stronger, but less ductile

6-26. Aluminum alloys that reach full strength after 4 or 5 days at room temperature are natural aged alloys, and those that require precipitation thermal treatment to develop their full strength are artificially aged alloys.

6-27. The purpose of refrigerating aluminum that has been solution heat treated is to

1. increase its ductility
2. increase its corrosion resistance
3. retard its rate of natural aging
4. accelerate its rate of natural aging

● Refer to table 5-2 in your textbook in answering items 6-28 and 6-29.

6-28. What condition is indicated if aluminum alloy is numbered 2024-T86? The alloy has been

1. fully annealed
2. strain hardened and then stabilized
3. solution heat treated, artificially aged, and then cold worked
4. solution heat treated, cold worked, and then artificially aged

6-29. Which of the following aluminum alloy designations indicates that the metal has been solution heat treated and then artificially aged?

1. 3003-F
2. 5052-H36
3. 6061-O
4. 7075-T6

6-30. A temperature of 775°F should be used in annealing which of the following aluminum alloys?

1. 1100
2. 3003
3. 5052
4. 5056

6-31. What is the best temperature for annealing 5052 aluminum alloy to obtain maximum drawability?

1. 600°F
2. 650°F
3. 700°F
4. 750°F

6-32. How long and at what temperature should 2024 aluminum alloy be soaked before air cooling in order to remove the effects of strain hardening due to cold work?

1. One hour at 640° to 660°F
2. Two hours at 750° to 800°F
3. Two hours at 640° to 660°F
4. One hour at 675° to 700°F

6-33. If aluminum is to be formed without annealing, it should be done immediately after

1. heating
2. quenching
3. anodizing
4. aging

Learning Objective: Identify characteristics and uses of different type aluminum alloy rivets.

6-34. Relative to use at the airframes work center level, which of the following groupings of aluminum alloy rivets is consistent?

1. 1100, 2017, 5056
2. 1100, 2117, 5056
3. 2017, 2024, 2117
4. 1100, 2017, 2024, 2117, 5056

6-35. Rivets of which alloy are most widely used in aircraft construction?

1. 1100
2. 2117
3. 2024
4. 5056

6-36. If alloy 2024 rivets are not refrigerated, they should be driven within 20 minutes after they have been quenched; otherwise, before being used, they must be

1. aged
2. anodized
3. discarded
4. reheat treated

6-37. Heat treatment procedures for 2017 and 2024 aluminum alloy rivets differ in that 2017 rivets require

1. greater temperatures
2. quenching in water
3. less time to develop maximum shear strength
4. all of the above

Learning Objective: Indicate the effects of heat treating magnesium alloys, and the dangers of exceeding their maximum temperature range.

6-38. Magnesium alloys are at their hardest after they have been

1. solution heat treated
2. quenched in water
3. artificially aged
4. naturally aged

6-39. Which of the following qualities of magnesium alloy are improved by precipitation heat treatment?

1. Ductility and toughness
2. Hardness and yield strength
3. Ductility and yield strength
4. Hardness, toughness, and yield strength

6-40. The most serious consequence of exceeding the maximum temperature range of a magnesium alloy casting during heat treating would most likely be that the

1. casting would melt
2. furnace would explode
3. casting would catch fire
4. soaking time would have to be increased

Learning Objective: Recognize characteristics of titanium alloys and indicate heat treating processes used.

6-41. Titanium's greatest advantage in airframe construction is its

1. ability to withstand high temperatures
2. high strength-cost ratio
3. high strength-weight ratio in the temperature range from 250° to 1,000°F
4. high corrosion resistance in the temperature range from 100° to 1,000°F

6-42. How does the springback resulting from forming alloyed titanium compare with that for stainless steel?

1. It is approximately equal to that for 1/4-hard 18-8 stainless steel
2. It is approximately equal to that for 1/2-hard 18-8 stainless steel
3. It is 25 percent greater than that for 1/4-hard 18-8 stainless steel
4. It is 25 percent greater than that for 1/2-hard 18-8 stainless steel

6-43. Hot forming titanium will result in

1. smaller bend radii
2. increased elongation
3. less springback
4. all of the above

6-44. All of the following heat-treatment processes can be performed on pure titanium except

1. thermal hardening
2. stress relieving
3. full annealing
4. casehardening

6-45. Which process for titanium alloys requires the highest temperature?

1. Nitriding
2. Carburizing
3. Carbonitriding
4. Stress relieving

Learning Objective: Indicate capabilities and techniques relative to heat treating furnaces.

6-46. What is the maximum temperature to which metal can be heated in the electric furnaces currently in use?

1. 940°F
2. 1,250°F
3. 2,000°F
4. 2,500°F

6-47. Heat treating rivets is generally done in which of the electric furnaces available from Aviation Supply Stock?

1. Basket type, automatic temperature control
2. Salt bath type, recording and controlling potentiometer
3. Box type, heavy duty with automatic temperature control, Brown controlling potentiometer
4. Either 1 or 3 above

6-48. Inasmuch as a delay of more than a few seconds can prove to be detrimental to the effectiveness of heat treatment, it is recommended that the quenching tank be located so that rapid transfer of the charge from the furnace to the quenching medium is possible.

Learning Objective: Recognize the operating principle and procedures for testing the hardness of metals with the Brinell, Rockwell, Riehle, and Barcol testers.

6-49. Testing the hardness of ferrous metals with the Brinell tester requires less pressure but more time than does the testing of the hardness of nonferrous metals.

6-50. Refer to table 5-3 in your textbook. You are testing a piece of steel on the Brinell tester and find the diameter of the ball impression to be 2.35 mm. What is the Brinell hardness number for the steel?

1. 114
2. 124
3. 682
4. 745

6-51. The Rockwell hardness tester measures the depth of the impression on the metal being tested, and the Brinell tester measures the diameter of the impression.

6-52. You are testing a piece of steel on the Rockwell tester using the diamond penetrator and both weights. If the reading is 40 on the black scale and 70 on the red scale, what is the Rockwell hardness number of the steel?

1. B-40
2. B-70
3. C-40
4. C-70

6-53. Refer to table 5-4 in your textbook. In using the Rockwell hardness tester, the black dial numbers should be read only when using the

1. E-scale
2. F-scale
3. 1/16-inch ball penetrator
4. diamond penetrator

6-54. How should the pan be weighted when making a G-scale test on the Rockwell testor?

1. With the red weight only
2. With the black weight only
3. Without weight
4. With both weights

6-55. Metal to be tested on the Rockwell tester must meet which of the following specifications?

1. The two opposite ground surfaces must be free of scratches and foreign matter
2. It must be ground smooth on two opposite sides
3. The two opposite ground surfaces must be parallel
4. It must meet all of the above specifications

6-56. The Riehle tester should not be used to obtain readings on Rockwell scale

1. B
2. C
3. F
4. G

6-57. Refer to table 5-4 in your testbook. When testing a metal of completely unknown hardness on the Riehle tester, a preliminary test should be made using the diamond penetrator with a major load of

1. 10 kg
2. 60 kg
3. 100 kg
4. 150 kg

6-58. Relative to the Barcol tester, which statement is false?

1. A damaged point should not be reground but should be replaced
2. The softer the material tested the lower the dial reading
3. The tester should be positioned so that the plunger drives the point into the metal at an angle of 90 degrees
4. The spring which drives the indenter must be adjusted if the indicated reading is not within the range of the test disc tested

6-59. You check the condition of the point of the Barcol tester by using the test disc and find the indicator reading is not within the specified range. You should correct this condition by

1. adjusting the lower plunger guide
2. adjusting the plunger upper guide nut
3. installing a new point
4. grinding the point

6-60. Refer to table 5-5 in your testbook. Which of the following aluminum alloys is the hardest?

1. 3003-0
2. 3003-1/2H
3. 5052-1/2H
4. 6061-T

Assignment 7

Corrosion Control; Nondestructive Inspection of Metals; Oxyacetylene Welding, Brazing, and Soldering

Text: **Pages** 187 - 221

DELETE ITEMS 7-1 THROUGH 7-11.

7-10. DELETE

7-11. DELETE

Learning Objective: Identify terms, uses, and application procedures and results associated with the magnetic particle inspection.

7-12. Not only can a defect in a ferromagnetic aircraft component be located by magnetic particle inspection, but also the defect's approximate size and shape can be determined.

In items 7-13 through 7-15, select from column B the definition of each term given in column A.

A. Terms

7-13. Permeability

7-14. Discontinuity

7-15. Indication

B. Definitions

1. The pattern formed by the magnetized particles in the magnetic field between the opposite poles
2. The ease with which a magnetic flux can be established in a given magnetic circuit
3. The ferromagnetic particles which are flushed or dusted over the part being tested or in which the part is immersed
4. An interruption in the normal physical structure or configuration of a part

7-16. How is the indicating medium (ferromagnetic particles) applied to a component in performing the magnetic particle inspection?
1. By dusting the particles, in dry form, over the component
2. By immersing the component in a liquid in which the particles are held in suspension
3. By flushing the component with a liquid in which the particles are held in suspension
4. By any of the above methods

7-17. When a ferromagnetic part is subjected to a magnetic particle inspection, the indication will appear and remain on the surface of the part immediately above and in the form of an approximate outline of the discontinuity because of the magnetism in the part and the adherence of the magnetic particles to each other.

7-18. The magnetic particle inspection is unreliable for detecting
1. laps
2. cold shuts
3. inclusions
4. discontinuities considerably below the surface

7-19. Which type of discontinuity is formed by a rupture of the metal?
1. Lap
2. Pipe
3. Cold shut
4. Inclusion

7-20. Which type of discontinuity will be formed if, during melting of the basic metal, bits of the furnace lining are picked up by the metal?
1. Void
2. Seam
3. Cold shut
4. Inclusion

7-21. Which of the following substances, if present on the surface of a part to be subjected to magnetic particle inspection, will prevent proper testing?
1. Zinc
2. Paint
3. Grease
4. Any of the above

Learning Objective: Recognize induction procedures and characteristics of methods used in the magnetization process, associated indications produced with various types of discontinuities, and areas to consider when interpreting results.

7-22. Inasmuch as it is essential that the magnetic lines of flux pass approximately parallel to the defect in order to locate it, it is necessary that they be induced in only one direction.

7-23. A satisfactory circular magnetic field can be produced on the inside surface of a hollow or tubelike part by wrapping a flexible electrical conductor around the part.

7-24. Which defects will not produce indications if a part is magnetized by continuous longitudinal magnetization with a cable?

1. Defects perpendicular to the axis of the part
2. Defects running from the center of the part out
3. Circular defects running around the part
4. Defects parallel to the axis of the part

7-25. Which method of magnetization produces the greatest sensitivity in locating subsurface discontinuities?

1. Residual circular without a conductor bar
2. Residual circular with a conductor bar
3. Continuous longitudinal with a coil
4. Residual longitudinal with a coil

7-26. The principal difference between the continuous and residual magnetizing methods lies in the time when the indicating medium is applied.

7-27. Indication shape, buildup, width, and sharpness of outline are generally more valuable in distinguishing between types of discontinuities than in determining their severity.

7-28. Which open-to-the-surface discontinuities produce the most readily distinguished indications?

1. Pipes
2. Cracks
3. Seams
4. Hairlines

7-29. Which type of cracks will probably cause the most buildup in the indicating medium?

1. Fatigue
2. Heat-treat
3. Shrink
4. Grinding

7-30. Which of the following is characteristic of a fatigue crack?

1. The part has been in service.
2. The discontinuity pattern has good buildup.
3. The discontinuity is found in a highly stressed area of the part.
4. All of the above are characteristic of a fatigue crack.

7-31. Which discontinuities are formed by nonmetallic materials that have been trapped in the ingot during solidification?

1. Laps
2. Hairlines
3. Inclusions
4. Segregations

7-32. Unlike the indication of a crack, the indication of an open inclusion usually consists of

1. a symmetrical pattern
2. a heavy buildup
3. a smooth outline
4. parallel lines

7-33. The magnetic particle inspection method is unreliable for detecting

1. hairlines
2. segregations
3. pipes considerably below the surface
4. nonmetallic inclusions

7-34. Consideration of which of the following areas would aid the inspector in interpreting a positive result?

1. Part processing methods
2. Material of which the part is made
3. Heat-treating and finishing operations
4. All of the above

Learning Objective: Recognize characteristics, uses, and components of various magnetizing units.

7-35. Refer to figure 7-14 in your textbook. Longitudinal magnetization is produced by which of the indicated components?
1. The contact heads
2. The nozzle
3. The coil
4. The contacts and pressure spring

7-36. The general-purpose portable magnetizing unit was designed for applying the suspension, supporting the work, and supplying the magnetizing and demagnetizing current.

7-37. In testing a crankshaft with a general-purpose portable magnetizing unit, longitudinal magnetization can be developed by
1. wrapping the cable around the crankshaft
2. using the contact prods
3. using the contact clamps
4. using the residual method

7-38. During automatic demagnetization operations with the general-purpose portable magnetizing unit, reduction of the output current is accomplished by the
1. prod assembly switch
2. control cable switch
3. motor-driven DEMAG switch
4. motor-driven rotary switch

7-39. DELETE

7-40. DELETE

7-41. DELETE

7-42. What is the purpose of providing prods with the standard general-purpose magnetizing unit?
1. To eliminate the necessity for bolted connections when using contact blocks
2. To permit testing of parts where it is impractical to use clamps
3. To prevent burning of the contact areas
4. To permit testing of propeller blades

7-43. Burning a propeller blade at the contact points during circular magnetization is prevented by the use of copper braid lined clamps at the blade tip and butt end.

Learning Objective: Recognize the liquid vehicles for wet suspension, the qualities the indicating medium must possess, and how the medium is mixed and applied.

7-44. Which liquid is acceptable as a vehicle for wet suspension of the magnetic particles?
1. Kerosene
2. Conditioned water
3. Drycleaning solvent
4. Any of the above

7-45. Which qualities must the indicating medium for magnetic particle inspection possess for acceptable operation?
1. High permeability and low retentivity
2. Low permeability and low retentivity
3. High permeability and high retentivity
4. Low permeability and high retentivity

7-46. Before the magnetic paste is added to the tank of suspension liquid, the paste must be mixed with a small amount of
1. dry magnetic powder
2. the suspension fluid
3. petroleum jelly
4. water

7-47. Application of the dry type magnetic particles may be accomplished by
1. rolling the magnetized part in the particles
2. pouring the particles directly on the surface of the magnetized part
3. floating the particles to the surface of the magnetized part
4. any of the above methods

Learning Objective: Identify the type and source of current for demagnetizing parts and the method of demagnetizing a part by means of the narrow coil demagnetizer.

7-48. What type of current is usually used to demagnetize aircraft parts?
1. Direct, increasing
2. Alternating, increasing
3. Alternating, decreasing
4. Direct, decreasing

7-49. Refer to figure 7-19 in your textbook. To use this unit properly, the part to be demagnetized must be suspended in the coil and remain there for the length of time specified for the size of the part and the strength of its magnetization.

7-50. Inasmuch as the portable electromagnet type demagnetizer requires a power source of about 3 amperes and 100 volts at 60 hertz, it can be plugged into most lighting circuits.

7-51. Direct current must be used to demagnetize a part that has been magnetized by the d-c mode of the Parker Contour Probe.

Learning Objective: Recognize advantages of radiographic inspections, and indicate familiarity with the exposure and interpretation processes and related safety precautions.

7-52. An advantage that a radiographic inspection has over the other types of nondestructive inspections of an aircraft structure is that the radiographic test requires little or no disassembly of the structure.

7-53. When an aircraft component having an internal discontinuity is subjected to a radiographic inspection, the density of the shadow the discontinuity produces on the film is much greater than that of the rest of the component.

7-54. Inasmuch as a surface condition shows clearly on an x-ray film, a visual inspection of a component to be x-rayed must be made prior to interpretation of the film to avoid reading surface features as internal discontinuities.

7-55. Only one person, the authorized radiographer, is allowed within the roped-off area in which radiographic operations are being conducted.

Learning Objective: Recognize operating principles of instruments used in ultrasonic inspections, and operating characteristics and uses of eddy current instruments.

7-56. Indications resulting from an ultrasonic inspection are reflected on a
1. tape recorder
2. cathode ray tube
3. photoelectric cell
4. supersensitive meter

In items 7-57 through 7-59, select from column B the type of ultrasonic search unit that utilizes each type of beam projection listed in column A.

	A. Projection Types	B. Search Unit Types
7-57.	Vibrations that travel along and just below the surface of the material being tested	1. Angle 2. Surface
7-58.	Vibrations that travel perpendicular to the surface of the material being tested	3. Immersion 4. Straight
7-59.	Vibrations that travel at a diagonal to the surface of the material being tested	

7-60. In addition to performing the function for which they were originally developed, that of locating cracks around spark plug ports of aircraft engine cylinders, the eddy current instruments can be used to furnish information concerning
1. magnetic permeability
2. electrical conductivity
3. hardness and tensile strength
4. all of the above

7-61. Coils and probes must always be used in pairs when performing inspections with the Magnatest ED-520 eddy current instrument.

7-62. Correct adjustment for probe compensation of the Magnatest ED-520 tester is indicated by the meter
1. reading constant when the probe is in contact with the surface of the part to be tested
2. fluctuating when a piece of paper is inserted between the probe and surface of the part to be tested
3. reading constant when a piece of paper is inserted between the probe and surface of the part to be tested
4. doing both 1 and 3 above

Learning Objective: Recognize the advantages of welded joints and of oxyacetylene welding, and identify the function of the gas welding torch and the temperature range of the oxyacetylene flame.

7-63. In addition to its high strength and the low cost of its production equipment, the welded joint has been universally adopted for the building of all types of aircraft because of
1. its rigidity
2. its simplicity
3. its low weight
4. all of the above

7-64. The function of the gas welding torch is to
1. grip the rod and direct it against the metal as the gas mixture is applied to the metal from the hose
2. protect the welder's hand from the intense heat generated by the puddled metal
3. provide a clamping device for the gas tubes and the rods so that they can be held as close together as possible when they join the flame at the point of contact with the metal
4. mix the gases in proper proportions and to direct the flame against the metal

7-65. The oxyacetylene flame will have an approximate temperature range of
1. 3,600° to 4,500° F
2. 4,700° to 5,600° F
3. 5,700° to 6,300° F
4. 6,500° to 8,300° F

7-66. Oxyacetylene welding and cutting are widely used by all types of maintenance activities because of
1. the low cost of gas production
2. the ease of regulating the flame
3. the ease and safety with which the equipment may be transported
4. all of the above

Learning Objective: Indicate the process of oxyacetylene welding, the type of oxygen cylinders and the safety precautions observed with acetylene.

7-67. Which statement relating to oxygen is false?
1. It is highly flammable.
2. It is heavier than air.
3. It is colorless, odorless, and tasteless.
4. It makes up approximately one-fifth of the volume of the atmosphere.

7-68. Approximately how many cubic feet of oxygen are present in 78 cubic feet of air?
1. 12
2. 16
3. 19
4. 21

7-69. The gas used for oxyacetylene welding aboard an aircraft carrier is a mixture of aviator's breathing oxygen and acetylene gas.

7-70. To distinguish it from technical oxygen, a cylinder of aviator's breathing oxygen is identified by its green color and
1. a white band around the top
2. white triangles on the side
3. a yellow band around the top and bottom
4. black letters on the side

7-71. Since acetylene will burn by itself in the air, why is oxygen necessary for gas welding?
1. It is cheaper than using acetylene alone.
2. It is safer than using acetylene alone.
3. Acetylene alone produces a low-temperature flame.
4. Acetylene alone produces too smoky a flame.

7-72. It is safe to use acetylene to weld if its pressure is
1. equal to the storage pressure
2. between 15 and 20 psi
3. 15 psi or below
4. above 16 psi

7-73. What is the maximum pressure to which acetylene is compressed in its cylinders?
1. 15 psi
2. 200 psi
3. 225 psi
4. 250 psi

7-74. When oxyacetylene welding, safety precautions include leaving the special T-wrench on the valve spindle after opening it, opening it slowly, and never opening it more than
1. 3/4 turn
2. 1 turn
3. 1 1/2 turns
4. 2 turns

7-75. Inasmuch as oxygen and acetylene are mixed for oxyacetylene gas welding, the regulators for each type of gas are interchangeable.

Assignment 8

Oxyacetylene Welding, Brazing, and Soldering

Text: Pages 222 - 248

Learning Objective: Indicate the composition of oxyacetylene used aboard aircraft carriers, how oxygen and acetylene cylinders are marked, and the physical properties of oxyacetylene, and recognize characteristics, uses, procedures, and safety precautions related to oxyacetylene welding equipment.

8-1. The standard Navy acetylene cylinder is a seamless steel shell with welded ends, 12 inches in diameter and 36 inches tall, and identified by its yellow color with acetylene written twice in 2-inch black letters lengthwise on the cylinder.

8-2. You are prevented from installing an oxygen hose on an acetylene regulator because the acetylene fitting
1. is larger
2. is smaller
3. has left-hand threads
4. has right-hand threads

8-3. The low-pressure gage on the oxygen pressure regulator of the portable welding outfit indicates the
1. working pressure of the oxygen
2. amount of oxygen in the cylinder
3. cylinder pressure of the oxygen
4. amount of oxygen being mixed with acetylene

8-4. Regulators that reduce the pressure of the gases from cylinder pressure to working pressure in one stage are generally used in portable welding outfits.

8-5. In which type torch is the oxygen pressure much greater than the acetylene pressure?
1. High-pressure
2. Low-pressure
3. Balanced-pressure
4. Medium-pressure

8-6. Refer to table 8-1 in your textbook. You are using an Airco tip No. 00 weld 1/8-inch steel straps. Which statement best describes the results?
1. The heat produced will be too great and will burn holes in the metal.
2. The depth of penetration will be less than is necessary to form a satisfactory weld.
3. The weld will be satisfactory since the heat produced is correct for the thickness of the metal.
4. The temperature produced will exceed safety limits and thereby cause a structural weakness in the metal.

8-7. If a torch tip becomes clogged while in use, it should be cleaned out with
1. a wire tip cleaner
2. a small diameter safety wire
3. a soft copper wire
4. either 1 or 3 above

8-8. Which features describe an oxygen welding hose and its fittings?
1. Red hose, grooved nut, right-hand threads
2. Black hose, grooved nut, left-hand threads
3. Maroon hose, plain nut, left-hand threads
4. Green hose, plain nut, right-hand threads

Learning Objective: Identify uses and characteristics of various types of welding flames, causes of flashback, and procedures for setting up and securing welding equipment.

8-9. The size and type of welding rod used is dependent upon
1. ductility and/or strength required of the weld
2. corrosion resistance required of the weld
3. the thickness of the metals to be joined
4. all of the above

8-10. A carburizing flame is usually used for welding
1. bronze
2. steel
3. aluminum
4. nickel alloy

In items 8-11 through 8-13, select from column B the class of flame that is identified by each condition listed in column A.

	A. Conditions	B. Flames
8-11.	More oxygen is used than acetylene.	1. Neutral
		2. Carburizing
8-12.	More acetylene is used than oxygen.	3. Oxidizing
8-13.	Equal amounts of oxygen and acetylene are used.	4. Acetylene

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8-14. If the flame becomes yellow and gives off smoke and soot during its adjustment, it could be an indication that there is no
1. acetylene in the cylinder
2. nitrogen at the torch
3. acetone in the cylinder
4. oxygen at the torch

8-15. To obtain a soft flame without a reduction in thermal output, you should use a larger tip and
1. open up both oxygen and acetylene needle valves until the neutral flame is clearly defined
2. close down both oxygen and acetylene needle valves until the neutral flame is quiet and steady
3. close down the oxygen needle valve and open up on the acetylene needle valve until the neutral flame is quiet and steady
4. open up on the oxygen needle valve and close down on the acetylene needle valve until the neutral flame is clearly defined

8-16. Which factor can cause a flashback?
1. Overheating of the torch
2. Loose connections
3. Improper pressures
4. Any of the above

8-17. While setting up the equipment, what has occurred if a pressure drop is noted on the working gage of the oxygen cylinder?
1. There is a leak between the oxygen regulator and the torch tip.
2. There is a leak in the hose between the acetylene cylinder and the torch tip.
3. The acetylene regulator gage has malfunctioned.
4. The system is functioning correctly and the pressure drop is an expected indication as soon as the torch is lighted.

8-18. AMS2 Tom Watson was oxacetylene welding when called by his division officer for a conference. Watson knew from past experience that he would be away for more than 15 minutes so he
1. extinguished the torch and closed the gas and oxygen cylinders
2. opened both torch needle valves and allowed all gas and oxygen in the hoses between the cylinders and the torch to escape
3. closed both regulators by backing out the adjusting screws until they were loose
4. completely secured the welding equipment in accordance with NAVMAT P-5100, Safety Precautions for Shore Activities

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Learning Objective: Recognize fundamental welding techniques, and identify types of welded joints and the specific techniques that are applicable to them.

8-19. The manner in which a welder should hold the torch depends upon which factor?
1. The type of joint being made
2. The class of flame being used
3. The kind of metal being welded
4. The thickness of the metal being welded

8-20. The exact angle at which a welder should incline the torch from the perpendicular depends on
1. the type of weld to be made
2. the thickness and type of the metal
3. the amount of preheating necessary
4. all of the above

8-21. Which welding technique generates the most heat and is preferred for a weld having a thick cross section?
1. Forehand with the torch 30 degrees from the vertical
2. Backhand with the torch 30 degrees from the vertical
3. Forehand with the torch 45 degrees from the vertical
4. Backhand with the torch 45 degrees from the vertical

8-22. Which joints are classified as fillet welds?
1. Lap and tee
2. Tee and butt
3. Corner and lap
4. Butt and corner

8-23. Puddle control is not a major problem in which type of welding position?
1. Vertical
2. Horizontal
3. Overhead
4. Flat

8-24. In making a vertical weld you should begin at the bottom and proceed upward using the forehand method with the tip inclined between 45 and 60 degrees.

8-25. A filler rod is not usually used to make which of the butt joints?
1. Plain
2. Flanged
3. Single bevel
4. Double bevel

8-26. Which type of welding joint is commonly used in spot welding?
1. Tee
2. Lap
3. Edge
4. Butt

8-27. Refer to figures 8-14 and 8-15 in your textbook. All of the following joints require that a filler rod be added for reinforcement except the
1. thick stock edge joint
2. thin stock edge joint
3. double fillet corner joint
4. single fillet corner joint

Learning Objective: Indicate melting points of specific metals, how to determine expansion and contraction, and the characteristics of a good weld.

- Refer to table 8-2 in your textbook in answering items 8-28 and 8-29.

8-28. Two metals that have the same melting point are
1. medium carbon steel and nickel steel
2. bismuth and lead
3. pure aluminum and copper
4. nickel and tin

8-29. The melting points of which of the following metals differ the most?
1. Molybdenum and wrought iron
2. Vanadium and pure aluminum
3. Stainless steel and cast zinc
4. Chromium and magnesium

8-30. You are welding a 4-foot seam between two sheets of 1/8-inch steel and allow for contraction and expansion by separating the sheets at the far end. Approximately how wide should this separation be at the far end?
1. 1/4 inch
2. 1/2 inch
3. 1 inch
4. 2 inches

8-31. When welding a long seam between two sheets of metal 1/8 inch thick, expansion and contraction of the metal tend to draw the seam together as the weld progresses. In order to prevent the seam from overlapping at the end the welder may
1. place the two pieces of metal so that there is an increasing allowance of distance between them
2. use chill bars to absorb the heat and keep it from spreading across the whole surface areas
3. preheat the metal sheets so that contraction will take place at the weld and shrinking will take place in the rest of the structure at approximately the same rate
4. do any of the above

8-32. The external appearance of a welded seam is an excellent indication of its internal quality.

Learning Objective: Recognize the susceptibility of various ferrous metals to welding, and indicate related preparations and welding techniques.

8-33. Which type of ferrous metal is most frequently welded by gas welding?
1. Cast steel
2. Wrought iron
3. Low-alloy steel
4. Low-carbon steel

8-34. The degree of difficulty encountered in welding steel is directly proportional to the carbon content of the metal.

8-35. Before welding, any varnish present on the edges of a piece of carbon steel may be removed by
1. sandblasting
2. burning it off with a torch
3. applying a 10-percent caustic soda solution followed by a thorough washing with hot water
4. either 1 or 3 above

8-36. Which welding technique should you use to weld carbon steel?
1. Forehand method, holding the neutral flame at a 60-degree angle to the surface of the work
2. Backhand method, holding the oxidizing flame at a 30-degree angle to the surface of the work
3. Forehand method, holding the slightly carburizing flame at a 45-degree angle to the surface of the work
4. Backhand method, holding the carburizing flame almost perpendicular to the surface of the work

8-37. The techniques used in welding chrome-molybdenum steel differ from those used in welding carbon steel in which of the following respects?
1. The type of flame used
2. The preheating procedure employed
3. The type of filler rod used
4. All of the above respects

8-38. When welding chrome-molybdenum steel, a filler rod made of what material should be used?
1. Chrome-molybdenum steel
2. Low-carbon steel and vanadium
3. Chrome-molybdenum steel and vanadium
4. Stainless steel

8-39. Oxyacetylene welding should not be used to weld chrome-molybdenum steel thicker than 0.093 inch.

8-40. Before butt welding two 0.043-inch sheets of stainless steel, you should prepare the edges by
1. beveling
2. notching
3. beveling and notching
4. forming a flange

Learning Objective: Identify types of nonferrous metals that can be gas welded, and recognize related welding preparations and techniques.

8-41. You are not permitted to gas weld which aluminum alloys?
1. 1100
2. 2024
3. 6056
4. 6063

8-42. Relative to gas welding aluminum, which statement is incorrect?
1. Sheets of aluminum less than 0.125 inch in thickness constitute the majority of aluminum that is gas welded.
2. The puddled aluminum solidifies rapidly following the passage of the gas welding torch
3. Although the strength of aluminum alloy 2014 is improved by gas welding, its resistance to corrosion is impaired.
4. It is difficult to avoid causing a hole in a sheet of aluminum if a neutral flame, held perpendicular to the metal, touches the metal.

8-43. The edges of 0.198-inch thick aluminum should be prepared for welding by being
1. flanged only
2. beveled only
3. flanged and notched
4. beveled and notched

8-44. What should be used to remove dirt, grease, or oil from the surface of aluminum that is to be welded?
1. A solvent-soaked rag
2. A sandblasting outfit
3. A stainless steel wire brush
4. A 10-percent caustic soda solution

8-45. Filler rod 1100 will be used when welding which aluminum alloy?
1. 2014
2. 2017
3. 3003
4. 6063

8-46. Because of its corrosive properties, aluminum flux paste should be kept in a copper container.

8-47. Which statement relative to the welding techniques that you should use with 0.125-inch aluminum sheet is true? You should use the
1. backhand method and hold the slightly carburizing flame almost perpendicular
2. forehand method and hold the neutral flame less than 30 degrees above horizontal
3. backhand method and hold the oxidizing flame about 60 degrees above horizontal
4. forehand method and hold the carburizing flame between 30 and 45 degrees above horizontal

8-48. Gas welding of magnesium alloy is presently used only for emergency repairs because of the
1. intense heat it requires
2. corrosive qualities of its flux
3. low melting temperature of the metal
4. low kindling temperature of the metal

8-49. Unlike 0.050-inch magnesium, 0.150-inch magnesium when being butt welded requires
1. the use of flanged edges
2. the use of beveled edges
3. a 1/8-inch separation between the joint edges
4. a 3/32-inch separation between the joint edges

8-50. The third step in cleaning the flux off a finished weld on magnesium involves the use of
1. 1-percent citric-acid solution
2. 10-percent sulfuric acid solution
3. hot water and a stiff bristle brush
4. a wire brush

Learning Objective: Recognize characteristics and procedures associated with cutting ferrous materials with an oxyacetylene torch.

8-51. Cutting ferrous metal with an oxyacetylene torch is simply a speeded-up process of rusting that is induced by artificial means.

● In items 8-52 through 8-55, assume that you are watching a welder cut through a sheet of steel with an oxyacetylene torch using an oxygen pressure of 80 pounds. A shower of sparks is falling from the underside of the sheet.

8-52. The metal on the face and sides of the cut is being heated directly by the
1. molten oxide
2. torch flame
3. oxygen jet
4. acetylene jet

● Refer to table 8-3 in your textbook in answering items 8-53 through 8-55.

8-53. What acetylene pressure is the welder using?
1. 4 pounds
2. 5 pounds
3. 6 pounds
4. 8 pounds

8-54. How thick a piece of steel could the welder cut without changing torch tips?
1. 2 inches
2. 5 inches
3. 10 inches
4. 15 inches

8-55. The shower of sparks from the underside of the material indicates that the welder has
1. partially depressed the oxygen control lever on the cutting torch
2. started cutting the metal
3. used too much oxygen too soon
4. accomplished both 1 and 2 above

8-56. After you have completed a cutting operation with an oxyacetylene torch, you should extinguish the torch by first closing the acetylene valve and then closing the oxygen valve.

Learning Objective: Recognize different types of brazing and brazing techniques employed.

8-57. The term brazing includes all but which of the following processes?
1. Bronze welding
2. Hard soldering
3. Silver soldering
4. Stainless steel welding

8-58. Brazing is useful because of the low heat required and its ability to join many types of metals, and it is particularly useful in the maintenance of aircraft support equipment because of
1. its tendency to anneal the area to which it is applied
2. its ability to withstand heavy compression and impact loads
3. its high penetration-to-strength ratio
4. all of the above

8-59. The filler rod used for brazing brass should have a melting point of approximately
1. 1,450°F
2. 1,600°F
3. 1,750°F
4. 1,800°F

8-60. In brazing, flux is usually added to the
1. hot filler rod
2. hot base metal
3. cold filler rod
4. cold base metal

8-61. A joint should not be brazed under which of the following conditions?
1. The base metal has too high a melting point.
2. The finished joint must withstand very high temperatures.
3. The metals to be joined are not the same.
4. The metals to be joined have been heat treated.

8-62. When brazing brass you must be very careful to prevent the required oxidizing torch flame from burning which component of the alloy?
1. Tin
2. Lead
3. Zinc
4. Copper

Learning Objective: Recognize characteristics of silver soldering and soft soldering and indicate procedures and materials utilized.

8-63. The principal use of silver soldering, one of several methods of brazing, is to join parts that will be subjected to high temperature and vibration.

8-64. Since silver solder is relatively strong and has a high melting point, it is used primarily as a filler metal.

8-65. What is the minimum amount of lap which should be allowed when silver soldering a lap joint between two sheets of 1/8-inch copper if the joint is to be as strong as the base metal in the heated area?
1. 1/4 inch
2. 1/2 inch
3. 1 inch
4. 2 inches

8-66. Which type of torch flame is preferred for silver soldering?
1. Soft neutral
2. Harsh neutral
3. Soft carburizing
4. Harsh carburizing

8-67. If an electrical connection that has been sealed with soft solder is accidentally placed under prolonged heavy tension, the solder is likely to
1. increase the electrical resistance of the circuit
2. melt after a long period of use
3. strengthen the connection and prevent failure
4. yield gradually and produce failure

8-68. Before being used, a soldering copper must be tinned. This is done by
1. reshaping the point and coating it with resin
2. placing a thin unbroken film of oxide on the surface of the point
3. sharpening the surface of the point and coating it with sal ammoniac
4. placing a thin unbroken film of solder over the entire surface of the point

8-69. Why is resin flux commonly used for soldering electrical connections?
1. To prevent corrosion caused by residual traces of other type fluxes
2. To prevent contamination of the soldering iron
3. To dissolve oxides from the solder and the work
4. To harden the solder and prevent breakage

8-70. The process whereby two surfaces that have been previously tinned are joined and heated, causing the solder to run together and form a joint, is called
1. hard soldering
2. dual soldering
3. sweating
4. dual tinning

8-71. How should you remove the flux from copper that has been soft soldered?
1. Sandblast it lightly.
2. Boil it in a caustic soda solution.
3. Rinse it thoroughly with fresh, cold water.
4. Place it in a solution of sulfuric acid, sodium bichromate, and water.

Assignment 9

Electric Arc Welding; Gas Shielded Arc Welding

Text: Pages 249 - 281

Learning Objective: Recognize principles applicable to manual shielded metal arc welding and identify the term crater.

9-1. Which statement best describes the fusion process that takes place in manual shielded metal arc welding?
   1. The rod and the work are opposite electrodes, both melted by the heat of the arc, and the rod material is deposited on the work.
   2. An electrode closes the circuit by contact with the work, producing heat sufficient to melt the filler rod.
   3. A filler rod, introduced between positive and negative electrodes, closes the circuit.
   4. The arc heats the weld material, and the weld material drops on the work.

9-2. How does the welder first complete the electrical circuit?
   1. By touching the electrode to the work
   2. By touching the electrode clamp to the electrode
   3. By establishing an arc of proper length between electrode and work
   4. By increasing the current from the welding machine after grounding the work

9-3. What is the crater which is formed while welding?
   1. The molten metal at the tip of the welding rod
   2. The molten metal on the work where the arc touches
   3. The concave shape formed in the welding rod
   4. The ring of metal deposited on the work by the electrode

Learning Objective: Show familiarity with manual shielded metal arc welding machines and associated equipment as to classifications, sizes, operating characteristics, uses, and maintenance practices.

9-4. Welding machines are classified according to the
   1. voltage output
   2. current output
   3. type of current used
   4. source of current

9-5. The size of a welding machine is determined by the
   1. current delivered
   2. current required for operation
   3. voltage delivered
   4. voltage required for operation

9-6. What size welding machine is most economically suited for aircraft welding?
   1. 200 ampere
   2. 300 ampere
   3. 400 ampere
   4. 600 ampere

9-7. Which statement applies to a dual-control direct-current welding machine?
   1. Both voltage and amperage are adjusted by a single control.
   2. Both voltage and amperage are adjusted by individual controls.
   3. Both voltage and amperage are automatically adjusted by the demands of the arc.
   4. Voltage is manually adjusted, and amperage is automatically adjusted by the demands of the arc.

9-8. Which type of welding machine is most likely to be used for emergency repair jobs in isolated areas?
   1. Alternating current (a-c) machine
   2. Motor-generator type a-c machine
   3. Direct current (d-c) machine
   4. Engine-driven generator type d-c machine

9-9. The leads of an a-c welder are connected to the
1. primary coil
2. secondary coil
3. movable core
4. tapped winding of the primary coil

9-10. Continuous current control of a-c welders can be accomplished by all but which of the following current control methods?
1. Bridge reactor
2. Movable coil
3. Movable core
4. Tapped secondary coil

9-11. Rectified d-c welders contain which of the following three-phase components?
1. Full wave, high voltage plate type rectifier
2. Adjustable reactor
3. Transformer
4. All of the above

9-12. The rectified d-c welding machine offers which of the following advantages to make it the most adaptable for Navy welding?
1. Greater efficiency, therefore greater economy
2. Rapid response to change in current and voltage conditions
3. D-c and a-c welding
4. Both 1 and 2 above

9-13. Relative to the maintenance of welders, all the following are recommended procedures except
1. cleaning with solvent
2. cleaning with dry compressed air
3. greasing at each monthly inspection
4. removing the source of power prior to performing maintenance which requires dismantling the machine

9-14. Which of the following precautions should you take in greasing a welding machine?
1. Keep the machine running.
2. Turn the machine off until greasing is completed.
3. Do not put in so much grease that it will run out of the plug hole.
4. Be sure the plug is in place so that you will not throw grease on the commutator.

9-15. How should you shape new brushes to be installed in a welding machine?
1. Sand them to a perfect fit.
2. Shape them by running them in for a short while.
3. Shape them to a template of the commutator shape.
4. Wrap fine emery cloth around the armature and turn by hand to work in the brushes.

9-16. The size of the welding cables on a welding machine varies according to the
1. voltage delivered and the distance from the work
2. voltage delivered by the machine
3. distance of the machine from the source of power
4. distance from the work and current delivered

9-17. The main factor in determining the size of an electrode holder for a welding machine is the
1. amperage rating of the machine
2. size of the work
3. type of machine
4. diameter of the welding rod

9-18. When welding with an a-c welding machine the operator should use a fully insulated electrode holder which provides him greater protection from accidental shock.

9-19. In order to provide an efficient welding circuit, reduce or eliminate shocks from stray currents, and prevent full supply voltage from reaching the output terminals because of insulation breakdown, you should ground
1. the work
2. the welding bench
3. the welding machine frame and enclosure
4. all of the above

9-20. The glass window of a welder's shield is designed to allow the transmission of
1. all of the visible light only
2. infrared rays and part of the visible light only
3. ultraviolet rays and part of the visible light only
4. part of the visible light only

9-21. Refer to table 9-1 in your textbook. With which welding lens should your protective shield be equipped if you are to weld with a 300-ampere machine.
1. 8
2. 10
3. 12
4. 14

9-22. When performing welding operations you should
1. wear the protective clothing
2. wear flash goggles to protect your eyes when your face shield is removed
3. insure that there is adequate ventilation
4. observe all of the above safety precautions

Learning Objective: Recognize characteristics and uses of a-c and d-c welding machines and pertinent facts about welding current, voltage, and polarity.

9-23. Relative to the a-c and d-c welding processes, the polarity of a d-c machine always remains the same, but in an a-c machine the polarity continuously reverses itself.

9-24. Advantages of an a-c welding machine include
1. adaptability to single or multiphase outlets of 110, 220, and 440 volts
2. quiet transformer action
3. reduced arc blow
4. all of the above

9-25. Compared with d-c welding machines, a-c machines are usually
1. safer
2. noisier
3. more expensive
4. more sensitive to line surges

9-26. Which type welding machine should be installed in a shop that is to specialize in the repair of small nonferrous parts?
1. A d-c welder
2. An a-c welder with reversible polarity
3. An a-c welder with negative polarity
4. An a-c welder with straight polarity

9-27. In comparing d-c welding equipment with a-c welding equipment, the d-c equipment has which of the following disadvantages?
1. More expensive operation and maintenance
2. Greater initial cost
3. Greater power requirements
4. All of the above

9-28. The quality of the weld and the speed at which you weld depend upon the arc force which is controlled by the amount of current and voltage being used.

9-29. The predominant factor in determining the voltage across an arc is the arc's
1. force
2. length
3. temperature
4. gaseous content

9-30. A straight polarity welding circuit is one in which the electrode is connected to the negative side of the arc.

9-31. Straight polarity is particularly advantageous when welding cast iron and nonferrous metals.

9-32. What conclusion should you reach if you see an experienced welder drawing a bead with an E6010 electrode which smokes excessively?
1. He is using reverse d-c polarity
2. He is checking his polarity setting
3. He is using a bare electrode on an iron casting.
4. He is using a coated electrode on a nonferrous casting.

Learning Objective: Recognize effects of different factors affecting manual shielded metal arc welding.

In items 9-33 through 9-35, select from column B the most probable effect of each factor affecting welds listed in column A.

	A. Factors	B. Probable Effects
9-33.	Advancing the arc too slowly	1. Increased arc force
9-34.	Holding a long arc	2. Splatter
9-35.	Increasing the current	3. Unfused base metal
		4. Undercutting

9-36. Better penetration will result if you increase the current and simultaneously
1. speed up arc travel and keep proper arc length
2. lay in the bead faster and lengthen the arc
3. speed up arc travel and decrease arc length
4. maintain the correct arc length and slow down the rate at which you draw the bead

9-37. Welding with an a-c welding machine results in less arc blow than welding with a d-c welding machine because the constantly reversing polarity of the a-c machine
1. prevents arc force from building up
2. causes less splatter from the puddle
3. distributes the heat evenly between the electrode and the work
4. reduces the strength of the magnetic field caused by the arc

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Learning Objective: Recognize characteristics and uses of electrodes.

9-38. The addition of iron powder to the coating of some electrodes serves to
1. improve the weld appearance
2. increase the speed of welding
3. add additional metal to the weld deposit
4. do all of the above

● Items 9-39 through 9-44 refer to table 9-2 in your textbook.

In items 9-39 through 9-42, select from column B the welding position(s) in which each electrode listed in column A can be satisfactorily used.

	A. Electrodes	B. Welding Positions
9-39.	E6013	1. Flat only
9-40.	E6020	2. Horizontal fillet and flat
9-41.	E6024	
9-42.	E6030	3. Flat, vertical, overhead, and horizontal

9-43. Which electrode can be used only with d-c reverse polarity?
1. E6011
2. E6015
3. E6027
4. E6030

9-44. Which electrodes can be used with a-c or d-c reverse polarity?
1. E6010 and E6024
2. E6011 and E6018
3. E6013 and E6024
4. E6020 and E6027

9-45. Prior to performing a welding job, what is the first factor you must determine in order to select the proper electrode?
1. The welding position you will use
2. The type of joint you will make
3. The type of welding machine you will use
4. The kind of metal you will weld

9-46. Electrodes which have deep-penetration characteristics are not required for
1. an overhead weld
2. a vertical weld
3. a flat weld
4. a horizontal weld

9-47. Which of the following defects can be overcome by using the proper electrode?
1. A rusty joint
2. A poorly fit up joint
3. Plated metal at the joint
4. All of the above

Learning Objective: Recognize procedures and techniques for setting up a manual shielded metal arc welding machine, preparing the work, and commencing and completing the weld.

9-48. What should be the preliminary control settings on a d-c dual-control welding machine prior to striking the first arc?
1. Low voltage and high amperage
2. High amperage and voltage
3. Low amperage and high voltage
4. Low amperage and voltage

9-49. What corrective action should you take if, while you are welding, you observe that the electrode is excessively hot and the bead is rough and nonuniform?
1. Increase the current or use a larger electrode.
2. Increase the current.
3. Use a larger electrode and reduce the current.
4. Use a larger electrode or reduce the current.

9-50. Which factors govern the preparation of the joint to be welded?
1. The facilities available for preparing the metal
2. The kind of joint to be welded and the thickness of the metal
3. The direction of welding and the load to which the weld is to be subjected
4. All of the above

9-51. Which of the types of welding joints can be of either the bead or groove type, according to the preparation of the joint?
1. Lap
2. Tee
3. Butt
4. Corner or edge

9-52. One way you can determine that the arc is the proper length is by
1. feeling the temperature of the electrode
2. comparing it to the diameter of a coated electrode
3. noting how deep it penetrates
4. adjusting the distance between the electrode and the metal until a sharp crackling sound is obtained

9-53. In order to maintain the arc and form a uniform bead, movement of the electrode should be
1. down only
2. across the joint only
3. along the joint and down
4. across the joint and up

9-54. Which welding technique will enable you to work longer without becoming tired?
1. Keeping your elbows away from your body
2. Using your free hand to support the cable
3. Draping the cable over your shoulder
4. Gripping the electrode holder very tightly

9-55. Refer to figure 9-15 in your textbook. If, while performing a welding operation, you break the arc in order to replace the electrode, where should you restart the arc?
1. In the center of the crater and then move rearward to the weld bead
2. In the center of the crater and then bring forward to the work metal
3. Just ahead of the crater on the work metal and then return to the back edge of the crater
4. Just back of the crater on the weld bead and then bring forward to the front edge of the crater

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Learning Objective: Recognize techniques and procedures for position welding, and identify standard welding symbols.

9-56. Which of the following is determined by welding position only?
1. Arc length
2. Electrode size
3. Electrode type
4. Electrode polarity

9-57. What is the simplest way you can measure the depth of penetration of a bead weld?
1. Use a penetration gage.
2. Estimate the depth by eye while welding.
3. Saw through a steel test plate and measure the cross section obtained.
4. Check the depth of the crater at the end of the bead.

9-58. In groove welding a butt joint, the width of the first bead is determined by the
1. space between the roots of the joint
2. thickness of the metal
3. size of the electrode
4. type of groove

9-59. When welding a double groove weld, distortion may be controlled by
1. completing all passes on the first side, then turning the plate and staggering the passes on the second side
2. welding a complete pass alternately on each side, welding a half pass alternately on each side, then completing the passes on the second side
3. welding half of the passes on the first side, turning the plate and welding the passes on the second side, then turning the plate and completing the passes on the first side
4. welding half of the passes on the first side, turning the plate and welding half of the passes on the second side, turning the plate and welding the remaining passes on the first side, then turning the plate and completing the passes on the second side

9-60. Fillet welds are used to make what kinds of joints?
1. Lap and tee
2. Lap and butt
3. Tee and butt
4. Corner and edge

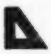
9-61. When performing overhead welding, which technique is common to fillet, groove, and bead welds?
1. Utilizing a backup strip
2. Maintaining a short arc
3. Weaving the electrode
4. Maintaining the electrode 90 degrees to the work

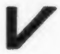
9-62. If, during overhead fillet welding, the puddle becomes too fluid and tends to sag, the welder should
1. withdraw the electrode and break the arc for a moment to allow the puddle to cool slightly, then start the arc several inches ahead of the puddle on the prepared groove
2. withdraw the electrode and break the arc for a moment to allow the puddle to cool slightly, then start the arc several inches behind the puddle
3. move the electrode quickly back over the bead for a moment to allow the puddle to cool slightly, then move the electrode quickly back to the crater
4. move the electrode quickly ahead of the bead and puddle for a moment to allow the puddle to cool slightly, then move the electrode quickly back to the crater

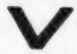
9-63. One difference between vertical welding and overhead welding is that in vertical welding you need to
1. maintain a short arc
2. vary the current according to the direction of welding
3. remove the slag after each bead is run
4. use weaving for all groove welds

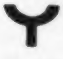
9-64. One way that you can get good control of the puddle when making a vertical fillet weld is by
1. hesitating at the center of each weaving motion
2. holding the electrode tilted slightly below the horizontal
3. keeping the arc slightly longer than the arc used for similar flatwork
4. using a current setting higher than the setting used for similar flatwork

9-65. Tee joints to be welded are usually marked on blueprints with which of the following symbols?

1. 

2. 

3. 

4. 

Learning Objective: Recognize characteristics and procedural techniques of the gas tungsten-arc (GTA) welding process and of the associated equipment and materials, including electrodes and gases used.

9-66. What is the basic advantage of GTA welding over other welding processes?
1. The gas, combined with the arc, produces more concentrated heat then is possible with either gas or electric welding alone.
2. It usually eliminates the need for filler metal, thus it is more economical.
3. It is much quieter than other welding processes.
4. It produces a weld similar to the metal being welded.

9-67. Which statement about GTA welding is false?
1. Either a-c or d-c current may be used.
2. The electrode is not consumed in the welding process.
3. Inert gas keeps the atmosphere away from the weld zone.
4. The use of a very intense electric arc in the absence of atmosphere requires that a very corrosive flux be used.

9-68. Which statement concerning GTA welding is incorrect?
1. It is a costlier operation than either gas or manual shielded arc welding.
2. A ventilating system must be used for removal of the fumes.
3. It may be used for joining dissimilar metals.
4. Postweld cleaning is not required.

9-69. Which type of current is required for welding heavy gage stainless steel?
1. Direct current reverse polarity (DCRP)
2. Direct current straight polarity (DCSP)
3. Alternating current low frequency (ACLF)
4. Alternating current high frequency (ACHF)

9-70. When performing GTA welding on aluminum, a line arc will be produced if the high-frequency current is shut off prior to removing the torch from the weld.

9-71. Which of the following combinations of factors will most likely result in a contaminated GTA weld?
1. DCSP, 0.020-inch electrode, 20 amps
2. DCSP, 3/32-inch electrode, 125 amps
3. DCRP, 1/4-inch electrode, 125 amps
4. DCRP, 1/16-inch electrode, 125 amps

9-72. Relative to a water-cooled GTA welding torch, which statement is true?
1. It automatically adapts to either alternating current or direct current provided straight polarity is used.
2. Water cooling enables the torch to be physically smaller but increases electrical power losses.
3. The path which the cooling water follows is from the hose, through the torch body, and out the discharge hose which surrounds the power cable.
4. The path which the gas follows is from the hose, through the torch body, through the gas cup, and out of the orifice in the torch head.

9-73. Which statement concerning tungsten electrodes alloyed with thorium is incorrect?
1. They are more expensive than pure tungsten electrodes.
2. They produce a more stable arc than pure tungsten electrodes.
3. They are more easily contaminated than pure tungsten electrodes.
4. They have a better current-carrying capacity than pure tungsten electrodes.

9-74. Under which condition will a ceramic cup be more desirable than one made of metal?
1. Excessive heat is dissipated.
2. Welding is performed under adverse conditions.
3. The welding current is approximately 200 amperes.
4. The welding current is approximately 300 amperes.

Assignment 10

Gas Shielded Arc Welding; Nonmetallic Materials

Text: Pages 281 - 316

Learning Objective: Recognize the characteristics and procedural techniques of the gas tungsten-arc (GTA) welding process and of the associated equipment and materials, including electrodes and gases used.

10-1. The rate of gas flow required during GTA welding could be affected by which of the following factors?
1. Arc length
2. Welding speed
3. Ventilation in the working spaces
4. Any of the above

10-2. One of the reasons why less argon than helium is needed for shielding during GTA welding is that argon
1. allows for the production of greater heat
2. remains in the weld area longer
3. enables the arc to penetrate deeper
4. offers more resistance to the passage of electricity

10-3. Which statement about identification of the argon and helium cylinders is correct? Both are painted gray, but the argon cylinders have
1. one white band at the top and the helium cylinders have two orange bands at the top
2. one orange band at the top and the helium cylinders have two white bands at the top
3. one white band at the top and the helium cylinders have one orange band at the top
4. two white bands at the top and the helium cylinders have two orange bands at the top

10-4. One difference between the alternating-current and the direct-current GTA welding machines is that with the direct-current machine
1. the cooling-water system is not needed
2. only straight polarity may be used
3. only a 220-volt power supply may be used
4. the torch may be attached to either terminal

10-5. The various special control units that have been developed to control automatically the various phases of the welding process may be used singly or in combinations in order to
1. conserve gas and water
2. reduce radio interference
3. provide greater convenience in operation
4. accomplish all of the above

10-6. What are the characteristics of the current produced by the high-frequency unit of the welding machine?
1. High frequency, low voltage, and low power
2. High frequency, low voltage, and high power
3. High frequency, high voltage, and low power
4. High frequency, high voltage, and high power

10-7. If you are to perform direct-current welding operations using equipment which is designed for either a-c or d-c welding, you should use the high-frequency unit to
1. obtain a more stable arc
2. increase arc length
3. establish the arc
4. increase electrode life

10-8. In the GTA welding machine, the maximum length of the arc is increased when the output of the high-frequency unit is increased and when the
1. diameter of the electrode is decreased
2. temperature of the electrode is increased
3. thickness of the work is decreased
4. density of the gas is increased

- Refer to table 10-1 in your textbook in answering items 10-9 and 10-10.

10-9. Which type of current is the first preference for welding 0.075-inch high-carbon steel?
1. ACHF
2. ACLF
3. DCRP
4. DCSP

10-10. Which is best suited for welding an aluminum casting?
1. ACHF
2. DCRP
3. DCSP
4. ACSP

10-11. When welding aluminum, the GTA process is preferred to the manual shielded metal arc process because the GTA process
1. produces deeper penetration into the metal
2. eliminates the need to reheat treat the metal
3. eliminates the problem of corrosion caused by flux
4. does not weaken the metal unless it has been annealed

10-12. In order to dissolve soluble constituents in the weld metal and both the coarse and fine precipitated particles in the base metal, heat-treatable aluminum alloys that have been welded must be reheat-treated before being used on aircraft.

10-13. The amperage required for welding aluminum and its alloys depends on
1. the size of the electrode
2. the thickness of the metal
3. the type of joint to be welded
4. all of the above

10-14. What type of filler rod should be used for welding 3003 aluminum alloy?
1. 1100
2. 4043
3. 5154
4. 5456

10-15. Oil or grease on a part to be welded must be removed either mechanically with a wire brush or chemically with nitric acid.

10-16. Which procedure should you use when using GTA welding equipment?
1. Clean the electrode with a commercial solvent before welding.
2. Start the arc on a piece of copper, scrap steel, or the work.
3. Thoroughly wire-brush the piece if it is aluminum.
4. Extend the electrode about 3/16 inch beyond the gas cup if making a fillet weld.

10-17. If you are GTA welding aluminum and for no apparent reason the arc rapidly moves from side to side, the most likely cause for this may be
1. the weld is not shielded from excessive air currents, or the electrode is contaminated with carbon
2. the electrode is too large for the amperage being delivered, or it is contaminated with carbon
3. the electrode is too large for the amperage being delivered, or the weld is not shielded from excessive air currents
4. any of the above

10-18. Which factor will usually displace the arc along the entire length of the weld?
1. Carbon contamination of the electrode
2. Low electrode current density
3. Magnetic effects
4. Air drafts

10-19. When welding aluminum without a filler rod, what motion should you apply to the GTA welding torch?
1. Straight line
2. Half moon
3. Figure eight
4. Butterfly

10-20. When a filler rod is being used, what motion should you apply to the GTA welding torch?
1. Straight line
2. Half moon
3. Oscillating
4. Figure eight

10-21. When a filler rod is being used, at what point do you deposit the rod material?
1. Just behind the arc
2. At the front of the puddle
3. In the middle of the arc
4. At the rear of the puddle

10-22. What is the most probable cause of the welding bead being too wide?
1. Too slow a rate of welding speed
2. An excessive rate of welding speed
3. An insufficient supply of gas
4. The electrode coming in contact with the weld metal

10-23. Refer to table 10-3 in your textbook. Which alloys represent the extremes of weldability of magnesium alloy?
1. AZ92A and AZ91B
2. ZK60A and AZ81A
3. HK31A and AZ63A
4. EK41A and ZK60A

10-24. Refer to table 10-4 in your textbook. If you are using DCRP in welding a sheet of magnesium and discover that a backing plate should be used, what adjustment should you make to the welding equipment after the plate has been placed in position?
1. Increase the current
2. Decrease the current
3. Switch to a.c.
4. Place the high-frequency switch in the OFF position

10-25. Which of the following can be used to mechanically clean magnesium alloy satisfactorily prior to welding?
1. A power-operated wire brush
2. Abrasive cloth
3. Steel wool
4. Any of the above

10-26. At what angle to the work should you hold the electrode when welding magnesium with GTA welding equipment?
1. 15°
2. 75°
3. 90°
4. As near parallel as possible

10-27. Which of the following describes the chief characteristics of austenitic steels?
1. They may be subjected to high temperatures, are nonmagnetic, and corrode easily.
2. They are nonmagnetic, contain either chromium or nickel, and are highly resistant to corrosion.
3. They are highly resistant to corrosion, contain chromium and nickel, and are magnetic.
4. They are nonmagnetic, highly resistant to corrosion, and contain chromium and nickel.

10-28. Refer to table 10-5 in your textbook. Which type of stainless steel requires postweld heat treatment?
1. 304L
2. 316
3. 316L
4. 347

10-29. Postweld heat treatment is not necessary when you weld alloy 321 because the alloy
1. is not an austenitic steel
2. contains titanium, which is highly resistant to intergranular corrosion
3. does not contain sufficient carbon to form carbides in the weld area
4. contains columbium, which is highly resistant to intergranular corrosion

10-30. Refer to table 10-6 in your textbook. When welding 0.125-inch stainless steel, what size filler rod should be used?
1. 1/16 inch
2. 3/32 inch
3. 1/8 inch
4. 3/16 inch

10-31. Which grouping is most applicable to the welding of stainless steel?
1. D-c straight polarity, electrode 1/8-inch below the gas cup, torch at an angle of 75 degrees to the work, 1/8-arc, filler rod at an angle of 10 degrees to the work
2. D-c straight polarity, electrode 1/8-inch below the gas cup, torch at an angle of 10 degrees to the work, filler rod never used
3. D-c straight polarity, electrode 1/8-inch below the gas cup, torch at an angle of 75 degrees to the work, 1/4-inch arc
4. High-frequency stabilized a-c, electrode 1/8-inch below the gas cup, torch at an angle of 10 degrees to the work, 1/8-inch arc, filler rod at an angle of 75 degrees to the work

10-32. Success in welding titanium requires
1. negative polarity
2. exclusion of oxygen and nitrogen from the root of the weld
3. the use of high-frequency stabilized alternating current
4. the use of a consumable electrode

10-33. What size thoriated tungsten electrode should be used for welding 0.032-inch titanium?
1. 1/4 inch
2. 3/16 inch
3. 1/8 inch
4. 1/16 inch

10-34. When welding titanium, the preferred method of gas shielding is to use
1. argon for both welding and backup shielding
2. argon for welding and helium for backup shielding
3. helium for both welding and backup shielding
4. helium for welding and argon for backup shielding

- Refer to table 10-7 in your textbook in answering items 10-35 and 10-36.

10-35. What type of power supply is recommended for welding 0.030-inch titanium?
1. ACHF
2. ACLF
3. DCRP
4. DCSP

10-36. Which factor for welding 0.060-inch titanium is the same as that for welding 0.090-inch titanium?
1. Voltage
2. Backup shield
3. Electrode travel
4. Primary shield

Learning Objective: Recognize characteristics of gas metal-arc (GMA) welding equipment and materials and indicate associated procedures.

10-37. Which statement relative to the GMA welding machine is false?
1. It operates on either a.c. or d.c.
2. It employs a consumable electrode in wire form.
3. Its output welding power is constant with respect to its welding current.
4. It cannot be used for manual shielded metal-arc welding because it has no current control.

10-38. What determines the welding current of the welding machine?
1. The stickout
2. The output voltage
3. The electrode size
4. The wire feed speed

10-39. The purpose of the thin copper coating on the surface of the consumable electrode wire used in the GMA welding process is to
1. help clean the weld metal
2. produce a smooth stable arc
3. prevent corrosion of the wire
4. increase the metal deposition rate

10-40. Carbon dioxide (CO_2) is a suitable shielding medium for GMA welding
1. aluminum
2. mild steel
3. stainless steel
4. all of the above

10-41. Since the welding circuit will stay energized until the wire electrode is withdrawn from the work, it is not necessary to keep the GMA welding gun trigger depressed once the arc has been established.

10-42. An experienced operator can determine when he has a properly established arc by observing the
1. amount of wire electrode being used
2. length of the arc
3. sound of the arc
4. color of the arc

Learning Objective: Relative to self-sealing and bladder type fuel cells, recognize characteristics of the cells and related construction features, including materials used, and indicate associated storage, maintenance, and repair practices.

10-43. In which order do the following actions take place when a self-sealing fuel cell is punctured by a bullet?
A. The bullet enters the outside wall of the cell.
B. The bullet passes through the cell wall into the cell.
C. The sealant swells after contact with fuel.
D. The sealant closes in behind the bullet.
E. The seal becomes complete.

1. A, D, C, B, E
2. A, C, B, D, E
3. A, D, B, C, E
4. A, B, D, C, E

10-44. What is the most common type of standard construction self-sealing fuel cell used in the Navy?
1. Semiflexible multiply
2. Nonflexible multiply
3. Semiflexible two-part
4. Nonflexible two-part

10-45. The inner liner of a standard construction self-sealing fuel cell is constructed of
1. nylon
2. natural rubber
3. Buna N synthetic rubber
4. Buna S synthetic rubber

10-46. Although Buna S is the most common type of synthetic rubber, it is unsuitable for use in standard construction self-sealing fuel cells because if it comes in contact with gasoline or gasoline vapor it will
1. dissolve
2. deteriorate
3. become hard and brittle
4. swell and eventually dissolve

10-47. The material commonly used for the sealant in a standard construction self-sealing fuel cell consists mainly of
1. rayon
2. natural gum rubber
3. Buna N rubber
4. Buna S rubber

10-48. Which of the plies of a standard construction self-sealing fuel cell will return the cell to its original shape if it should become punctured?
1. Sealer
2. Retainer
3. Inner liner
4. Nylon fuel barrier

10-49. Bladder type fuel cells possess which of the following advantages over self-sealing cells?
1. Easier to repair
2. Lighter weight
3. Lower cost
4. All of the above

10-50. Which of the following is a characteristic of a bladder type fuel cell?
1. It is self-sealing.
2. It requires a minimum of support.
3. It is made of thin material and is slightly larger than the cavity into which it will be fitted.
4. Its size makes it slightly heavier than the standard six-ply cell.

10-51. The fuel cell identified by the trade name Pliocel is which type of cell?
1. Nylon bladder
2. Rubber bladder
3. Self-sealing
4. Integral

10-52. What is the effect of the application of a thin coat of oil to the inner liner of an empty fuel cell?
1. It damps aromatic fuel vapors remaining in the cell.
2. It prevents drying and cracking of the inner liner.
3. It collects microscopic particles of foreign matter to aid removal during cleaning.
4. It does all of the above.

10-53. What is the first action you should take to stop a slight leak in a fitting installed in a fuel cell?
1. Replace the fitting.
2. Cover the edge of the fitting with acetone.
3. Cover the edge of the fitting with cement II.
4. Check the fitting for proper torque.

10-54. When replacing fuel cell stiffener rods, they should be lubricated with
1. soapy water
2. oil or grease
3. talc, and driven in place
4. any of the above

10-55. Handling precautions for fuel cells specify that before you excessively handle one that has been exposed to a temperature below 65° F you should warm it to room temperature.

10-56. Which condition is not required for the storage area for fuel cells?
1. Low humidity
2. Relatively cool temperature
3. Protection from direct sunlight
4. Continuously circulating air

10-57. Fuel cells should not be stored in the proximity of operating electrical equipment because of the tendency of synthetic rubber to deteriorate in the presence of
1. the electrical discharge into the air
2. the odor given off by electrical motors
3. the lubricants used in electrical motors
4. any of the above

10-58. Inasmuch as the temporary repair of a fuel cell would be as costly in time and effort as a permanent repair, all repairs currently made on them are permanent.

10-59. What must be done with a self-sealing fuel cell that has been ruptured to the extent that fuel comes in contact with the sealant if repair cannot be accomplished within 72 hours?
1. The cell must be drained.
2. The cell must be purged.
3. The cell must be preserved.
4. All of the above must be done.

10-60. Deciding whether to repair or replace a fuel cell depends on
1. the availability of repair materials
2. the availability of spare cells
3. the time required for the work
4. all of the above factors

● Items 10-61 through 10-63 refer to a bladder type fuel cell that has a 1-inch hole extending through its inner liner only.

10-61. Which patching arrangement should be used to repair the damage?
1. A single patch
2. A single outer patch and a double inner patch
3. A double outer patch and a single inner patch
4. Double inner and outer patches

10-62. To what approximate distance (in all directions) around the edge of the damage should the area be buffed?
1. 2 3/4 inches
2. 1 3/4 inches
3. 1/4 inch
4. 1/16 inch

10-63. In what order should you take the following steps to finish the repair correctly?
A. After the MEK solvent has dried, apply the necessary coats of cement.
B. Stitch or roll the patch down.
C. Inspect the patch for looseness after 2 hours have elapsed.
D. Center the patch over the area making sure that air is not trapped beneath it.
E. Allow the patch to remain undisturbed for 72 hours.

1. A, D, B, C, E
2. A, B, D, C, E
3. A, D, C, E, B
4. A, B, C, E, D

Learning Objective: Relative to integral fuel cells, indicate construction features, classes of leaks, and procedures for stopping leaks.

10-64. Which statement is incorrect relative to an integral fuel cell?
1. The cell is part of the structure of the aircraft.
2. The cell is ordinarily located between two spars and is capped off with sealed end ribs.
3. When milled skins are used to form the cell, they are riveted in place.
4. The mating surfaces of the cell are machined to extremely close tolerances and are further sealed with gaskets and sealants.

● In items 10-65 through 10-69, assume that during inspection of an integral fuel cell a leak is discovered. The leak is about 3 1/2 inches in diameter and reappears approximately 30 minutes after it is wiped off.

10-65. What classification should be given to the leak?
1. Running leak
2. Heavy seep
3. Slow seep
4. Seep

10-66. What is the first step you should take to stop the leak?
1. Replace the Stat-O-Seal washers under all fasteners in the leak area.
2. Replace the O-rings under all fasteners in the leak area.
3. Retorque all fasteners 6 inches on either side of the leak area.
4. Reinject sealant around the perimeter of the cell.

10-67. If the leak is around an O-ring seal, when you replace the seal it is very important that you do which of the following?
1. Back out the screw only far enough to remove the old seal, thus preventing cross-threading after the new seal is installed.
2. Remove the screw completely to prevent the possibility of breaking the new seal during its installation.
3. Install a washer between the seal and the nut plate to prevent recurrence of the leak.
4. Install a washer between the head of the screw and the seal to prevent recurrence of the leak.

10-68. If the leak persists after all preliminary procedures to stop it have been carried out, sealant should be reinjected. If there are four injection screws in the area of the leakage, how should the sealant be injected in order to reseal the perimeter of the cell?
1. Alternately into the holes until sealant flows out each one
2. Into each hole in order, making sure that the flow of sealant is always from the same direction
3. Into the two outside holes first, then into the center holes
4. Into the two center holes first, then into the outside holes

10-69. Which statement is true concerning the pressure test that is made on the repaired cell?

1. Nitrogen is used because it prevents an accumulation of fuel vapors.
2. Nitrogen is used because it does not present an explosion hazard.
3. Dry air is used because it is readily available.
4. Dry air is used because it does not present an explosion hazard.

Learning Objective: Recognize the operating principle and maintenance practices applicable to deicer boots and indicate safety precautions to be observed when performing sealant repairs.

10-70. Deicer boots help prevent dangerous ice accumulation by

1. preventing the formation of ice
2. melting the ice that forms
3. throwing off the ice that forms
4. cracking the ice that forms

10-71. It is good maintenance practice to periodically scrub deicer boots with an approved cleaning solvent.

10-72. What action must be taken if excessive contact with oil has caused a deicer boot to increase in width from 3 to 5 per cent?

1. Readjust the boot to its original tightness
2. Thoroughly clean the boot and treat it with an antioil agent
3. Replace the boot
4. Do both 1 and 2 above

10-73. During removal of a deicer boot, the cement bond can be loosened with

1. hot water
2. aromatic naphtha
3. aliphatic naphtha
4. the solvent recommended in the applicable Maintenance Instructions Manual

10-74. When you effect sealant repairs of any kind, you should be very careful to

1. wear protective clothing
2. use spark-proof tools
3. have adequate ventilation in the work area
4. observe all of the above precautions

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PRINT OR TYPE

AVIATION STRUCTURAL MECHANIC S 1 & C
NAVEDTRA 10311-C2

NAME ________________________________ ADDRESS ________________________________
Last First Middle Street/Ship/Unit/Division, etc.

____
City or FPO State Zip

RANK/RATE ______ SOC. SEC. NO. ____________________ DESIGNATOR ______ ASSIGNMENT NO. ______

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PRINT OR TYPE

AVIATION STRUCTURAL MECHANIC S 1 & C
NAVEDTRA 10311-C2

NAME ______________________ **ADDRESS** ______________________
Last First Middle Street/Ship/Unit/Division, etc.

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City or FPO State Zip

RANK/RATE ______ **SOC. SEC. NO.** ______________ **DESIGNATOR** ______ **ASSIGNMENT NO.** ______

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